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August 2010

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Looking for planets in dusty disks

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This beautiful two frame mosaic image of M42 and NGC1977 was taken with an SBIG self-guiding ST-2000XCM single-shot color camera by Ed Henry through an 80mm f/6 refractor

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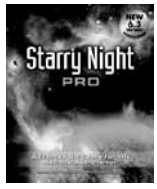

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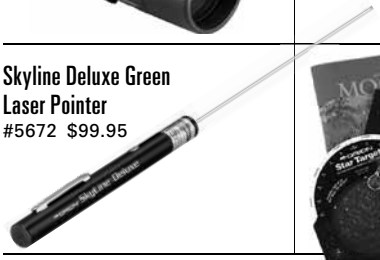

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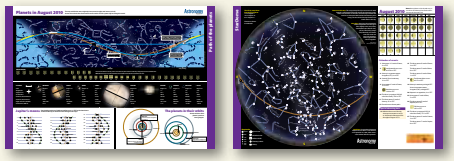

Path of the planets and StarDome.

Cover: *Astronomy*: Roen Kelly; Anthony Aylomamitis (moon image)

ON THE COVER
Massive dust disks surround many stars, potentially hiding any planets lurking within. But astronomers think that searching for gaps in these disks ultimately may reveal planets.

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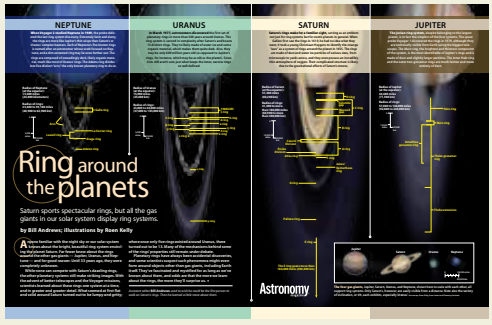

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ENGINEERED IN THE USA

New columnist: Tony Hallas

by David J. Eicher

The *Astronomy* magazine staff is excited to announce a new monthly column by world-renowned astrophotographer Tony Hallas. Next month, you will see the first installment of "Imaging the Cosmos," and we're sure you will glean an amazing amount of information from this column. Hallas is a great authority on imaging, and he has contributed to *Astronomy* for years. I remember meeting Hallas for the first time many years ago at a star party and immediately striking up a dialog about deep-sky objects and skyshooting that continues to this day.

Hallas has pioneered an elite level of color deep-sky astrophotography. Assisting him is his wife, Daphne. Time after time, the carefully produced prints of the Andromeda Galaxy, the Eagle Nebula, or the Pleiades that Hallas churned out invoked one response: "That's the best image I've ever seen!" Part of that comes from his expertise operating a professional color lab for many years. Part of it comes from Hallas' ability to choose interesting targets and to artfully process and present the final images. To preview some of his work, see www.astrophoto.com.

Tony Hallas

If you haven't seen Hallas' photos before, his images on the site will blow your mind. Anyone familiar with the Pinwheel Galaxy, for example, will see it in a new light. The huge number of star clouds, HII regions, and knots in the galaxy's arms will astonish you.

Starting with Hallas' first column next month, *Astronomy* will become an even more powerful resource for astroimagers. His subjects will focus on targets, lots on image processing, and a good deal on equipment to capture your own portraits of the cosmos. I expect it to be a widely read and very popular part of *Astronomy*'s future. Welcome, Tony!

***Astronomy* trips to Norway and Mexico**

I want to let you know about two fantastic trips we have coming in partnership with Melita Thorpe of MWT Associates. I will accompany readers on a trip November 2–11, 2010, to Norway to see spectacular aurorae while traveling aboard the Norwegian *MS Midnatsol*. The "Arctic Circle Northern Lights Tour" will use this luxurious vessel to host our trip from Bergen to Torvik, Trondheim, Tromsø, Hammerfest, and Kirkenes. We will see amazing Norwegian sights along the way in addition to our nightly sky shows. For more on this trip, see www.Astronomy.com/Norway.

Astronomy will also sponsor an excursion with MWT Associates to Mexico to see the legends of the Mayan civilization in "Dynasty of Mayan Kings," accompanied by columnist Bob Berman, January 11–20, 2011. This adventure includes the archaeological sites of Palenque, Yaxchilan, Uxmal, Chichen Itza, Tulum, and Coba. The group will also visit the nature reserve at Sian Ka'an, which holds 103 mammal species and 336 bird species. This special trip will surely prove highly memorable. For more information, see www.Astronomy.com/Mexico.

Yours truly,

David J. Eicher
Editor

Astronomy

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Stupendous stellar stamps

As a boy growing up during the first Moon landings, I was an avid stamp collector. I well remember collecting many stamps related to the space race and the various stages of lunar exploration.

Over the years, stamps from around the world have continued to celebrate a number of diverse astronomical topics. For instance, many countries issued special stamps during the 2009 International Year of Astronomy.

I thought you might be interested in seeing a small sample of astronomical stamps. Some feature constellations or asterisms, while others honor famous astronomers and scientists such as Copernicus, Galileo, and Kepler. Planets and other solar system objects also pop up, with Halley's Comet in particular featured on a diverse range of stamps from many countries. More recently, galaxies and deep-space objects as seen from powerful land- and space-based telescopes have appeared, too.

Anyone who's interested in collecting astronomical stamps may want to start online, as many good commercial websites have a wide variety for sale. I often look on eBay and just search "astronomy" under "stamps." It's a quick way to start a decent collection! **— David J. Kenny,** Courtenay, British Columbia

As these space-themed stamps show, a love for astronomy can transcend national borders, and even other hobbies. David J. Kenny

Peek at the sky and its stars

The monthly "Deep-sky Showcase" department is wonderful! At last you are putting to use David Eicher's experience as the editor of *Deep Sky* magazine so many years ago. Seeing those sketches of objects like galaxy NGC 253 and the Hercules Cluster (M13) makes me wish you had sketches in every issue — and now you do. Only a sketch can reveal those star chains.

"Astro Confidential" is great, too: At last we amateur astronomers get a peek at the lives of the professionals. I only wish you still carried book reviews in the magazine, but then one can't have everything. **— Julian Grajewski,** Hamburg, Germany

Different set of pipes

In March's "The Cosmic Grid," the entry titled "Astronettes?" mentioned the possible early female astronauts.

My brother worked for North American Rockwell in the 1960s and helped build the space capsules. He told me years ago about women and the early space program, and said that the main reason it took so long to get women into space was because designing space plumbing for them was a lot more difficult. He was the builder of the first space toilet, so I guess he would know! **— Ron Barnes,** St. Louis

This won't be on the final

I accidentally signed up for an astronomy class in college and ended up failing it miserably. But somehow the spark of an interest grew. I didn't know how to learn more or do anything about it until I found your magazine.

The "Astro News" section in particular always interests me due to its range and variety, and I loved your March story about Titan, "What we've learned about a strange new world." What spectacular pictures! Thanks so much for helping me fill in an educational gap that otherwise might have been lost for good. **— Ryan Van Cleave,** Sarasota, Florida

Science comes first

As a 17-year-old, I am the only teenage member of my local astronomy club, the Northeast Florida Astronomical Society. Unlike most amateur astronomers, for me the hobby has its roots not in the visual realm, but in the scientific elements of the field. I wanted to become an astrophysicist before I ever bought a telescope!

However, *Astronomy* magazine has helped me enjoy both sides of this wonderful hobby. I've been reading it for a little more than 2 years now, and even in that short time I have seen the magazine grow in the amount of interesting material it presents. **— Christopher Browning,** Jacksonville, Florida

Correction

In the April news story "Hubble Glimpses most-distant galaxies" (page 18), the galaxies in question should have been dated back to 600 million years after the Big Bang, not 600 million light-years. **— *Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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3. Prizes and Odds of Winning. One drawing will be held on or around September 21, 2010, for the following awards: One (1) Grand Prize consisting of a Celestron NexStar 8SE Telescope (retail value $1,199). One (1) First Prize consisting of a Celestron SkyMaster 15x70 Binoculars (retail value $89.95). One (1) Second Prize consisting of a Celestron TravelScope (retail value $79.95). One (1) Third Prize consisting of a Celestron FirstScope 50th Anniversary Edition (retail value $70). Ten (10) Fourth Prizes consisting of a subscription to *Astronomy* magazine (retail value $42.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 112,233. Sweepstakes void in Quebec and void where prohibited.

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Webtalk

Adam Block/Mount Lemmon Sky Center

Summer observing targets for large telescopes

In this video, *Astronomy* magazine Editor David J. Eicher shares 10 of his favorite summer deep-sky objects, including the Bug Nebula (NGC 6302), the Eagle Nebula (M16), Barnard's Galaxy (NGC 6822), and more.

MULTIMEDIA

Video: Cosmology 101: Dark Energy

Associate Editor Liz Kruesi explores what scientists know about dark energy, the mysterious force accelerating cosmic expansion.

Podcasts

Senior Editor Michael E. Bakich's weekly series identifies three notable objects or events you can see in your night sky.

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Strange Universe

by Bob Berman

Our bodies, our neutrinos

These strange particles pervade our universe but are difficult to detect.

The most abundant particle in the universe? It's the neutrino. They're everywhere, like roaches in Rio. Each second, about one trillion neutrinos whiz through your tongue. Don't taste a thing? That's because they rarely meddle with our bodies.

The neutrino was predicted 80 years ago to explain odd atomic behavior involving the neutron, whose name it resembles. Neutrons live in the center of atoms. They're the heaviest stable particle, and normally last forever. But if a neutron leaves its atom, it's toast. It then decays in 11 minutes or so.

A loose neutron is a loose cannon that goes *poof!* and turns into a proton and an electron. This debris tumbles away oddly, like defective fireworks, which convinced Wolfgang Pauli that something else must be present, too. He called the mystery item *neutrino*, which sounds like a kind of pasta but actually means "little neutral one."

A quarter-century passed before the neutrino was finally found. It was a scientific triumph, as well as a relief because neutrinos already figured theoretically in the fusion process that makes the stars shine. The Sun's core releases countless neutrinos, which essentially zoom away at light-speed and then don't interact with anything else, at least not in a normal way. Rather, they just pass through everything. Once in a Blue Moon, a neutrino will change an atom to something else — but it's rare.

By day, solar neutrinos penetrate your head and whiz completely through your body. At night, an equal number invades your body from below and exits your head, after having flashed through the entire Earth in ½₀ of a second.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

The chance that a neutrino will alter even one of your body's seven octillion atoms this year is one in a million. You need a wall of lead a light-year thick to stop the average neutrino. And who would build that? Those things aren't cheap.

Lately, we've found that they're even stranger than we imagined. Credit for this goes to physicist Ray Davis, who first figured out how to count these ghost particles. He probably got the idea after dripping pizza on his shirt because the apparatus is a huge vat of 100,000 gallons of cleaning fluid. Davis placed this a mile underground in an abandoned South Dakota gold mine. He figured a million pounds of tetrachloroethylene has enough chlorine atoms so that a neutrino will occasionally change one to a detectable form of argon. That was 40 years ago, and it actually worked, earning Davis the 2002 Nobel Prize 4 years before his death.

Lately, we've found that neutrinos are even stranger than we imagined.

But the Homestake gold mine experiment detected less than half the expected neutrinos. Were we wrong about the Sun's fusion process? Did Davis make some mistake? This "missing neutrino problem" drove astronomers bonkers for a quarter-century. The solution finally came in 2001, using a new detector in an Ontario nickel mine. The answer was nothing short of bizarre.

Neutrinos, which come in three different varieties, mutate as they fly through space! Imagine if, when out jogging, you suddenly turn into a golden retriever. A minute later, your new canine persona vanishes, and you're now trotting along as a happy orange tomcat. You're barely getting used to this when, shazaam, you're back to being you. And then the whole process repeats. Well, that's what neutrinos do. And the three varieties are quite different from one another.

Because the gold mine experiment could detect only one type of neutrino, Davis kept getting a "short count." Now his results make sense. Sort of.

Neutrinos can cause us to think about dark matter. How? Well, it's been obvious since 1933 that there's about 6 times more material in the universe than all the stars, nebulae, black holes, and everything else we can think of. This unseen stuff makes the Milky Way spin strangely. It glues together the Local Group of galaxies. Its gravitational pull is powerful. Yet it's invisible. And unlike fundraising telemarketers, it totally leaves us alone. We call this material dark matter because it does not emit, absorb, or even reflect light. Nor does it interact with our universe in any way we can yet detect aside from gravity. But each of its particles must be massive.

Because we now know the universe is filled with presto-change-o neutrinos that barely affect anything, dark matter no longer seems so preposterous. It would merely be a more extreme version. But might dark matter particles *attract each other* to form invisible structures? Is there a parallel universe, more sizeable than ours? It could be right here, right now, among us.

Neutrinos opened the door to strange new possibilities. Not to mention new ways to do dry cleaning.

Contact me about my strange universe by visting **skymanbob.com.**

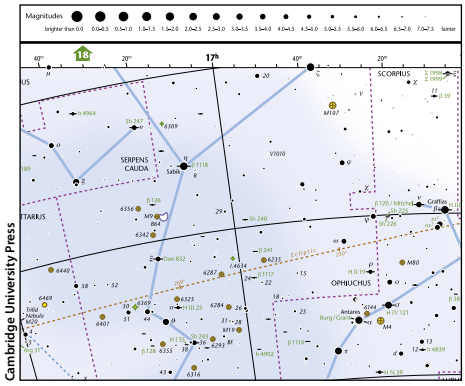
Observing Basics

by Glenn Chaple

Double star delights

These stellar couplings in Scorpius provide hours of enjoyment.

Psst! I've got a hot astronomical tip for you. Have you looked through your telescope at a double star lately? If not, you're missing out on one of the night sky's most stunning and beautiful sights. But why take my word for it? Spend an evening with the following stellar couplings in the western part of Scorpius. You can split most with telescopes as small as 2.4 inches (60 millimeters) and magnifications of just 50–75x.



Double star maps, like this one from *The Cambridge Double Star Atlas*, make finding stellar partnerships easy.

Start with one of the sky's premier doubles, Graffias, better known as Beta (β) Scorpii. Composed of magnitude 2.9 and 6.9 stars separated by 13.6", Beta Scorpii is reminiscent of the celebrated double star Mizar (Zeta [ζ] Ursae Majoris). Most observers report a distinct color contrast, describing the primary (brighter) as pure-white and the secondary as blue or blue-green. What do you see?

Just 2° east and slightly north of Beta Scorpii is the quadruple system Nu (ν) Scorpii, sometimes referred to as the southern "Double Double" because of its likeness to Epsilon (ε) Lyrae. Resolving all four members of the Epsilon Lyrae system is a piece of cake; Nu Scorpii, on the other hand, is a challenge. Its main components (magnitudes 4.2 and 6.6, respectively, with a separation of 41") are an easy mark for small telescopes, but you'll need a 6-inch scope, a magnification of 150x or more, and an evening of optimum seeing conditions if you hope to capture their close companions. The primary's magnitude 5.3 partner is a mere 1.3" away, while the secondary and its magnitude 7.2 companion are separated by 2.4".

A degree west of Psi (ψ) Ophiuchi is a much easier double-double formed by Sh 225 (magnitudes 7.4 and 8.1; 46.9" separation) and Sh 226 (magnitudes 7.6 and 8.3; 12.8" separation). These pairs, which British astronomers James South (S) and John Herschel (h) cataloged in 1824, are a visual delight when viewed together in the same low-power field.

For the grand finale, direct your attention 8° north of Beta Scorpii to the star Xi (ξ) Scorpii (magnitudes 4.9 and 7.3; 7.9" separation). Years ago when I first observed this striking pair with a 3-inch reflector, my eyes were drawn to a faint but pretty double star nearby. My resources identified the stellar duo as Σ1999 Scorpii (magnitudes 7.5 and 8.1; 11.8" separation). Xi Scorpii offers a bonus to anyone who examines its primary closely. It's a tight binary (magnitudes 4.9 and 5.1) with an orbital period of 46 years. Their current 1.0" separation is at the theoretical resolution limit for a 4-inch telescope. You'll have a more realistic chance of success with a 6-inch and a magnifying power of 200x for this pair.

Perhaps viewing these fascinating stellar partnerships will pique your interest in double stars. Remember, double stars are twice the fun!

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

Double star resources

BOOKS/ATLASES

- ***A Field Guide to Double Star Observing*** by Joe DalSanto (self-published, 2003) includes a list of more than 400 double and multiple stars.
- ***A Visual Atlas of Double Stars*** by Mike Ropolewski (The Webb Society, 1999) contains 124 pages of charts and data.
- ***Double Stars for Small Telescopes*** by Sissy Haas (Sky Publishing, 2007) offers data and descriptions of more than 2,100 double and multiple stars, arranged by constellation.
- ***The Cambridge Double Star Atlas*** by James Mullaney and Wil Tirion (Cambridge University Press, 2009) is a top-notch atlas devoted to double stars; it includes data for the nearly 2,400 double and multiple stars plotted and labeled in the atlas.

WEBSITES

- **www.saguaroastro.org/content/BEST-MULTIPLE-STARS.htm** — a list of the 110 "Best Multiple Stars," compiled by the Saguaro (Arizona) Astronomy Club.
- **www.astroleague.org/al/obsclubs/dblstar/dblstar2.html** — 100 showpiece double stars from the Astronomical League (AL).
- **www.richardbell.net/DoubleStars/dslog1.html** — color renditions of the 100 double stars in the AL list.
- **www.virtualcolony.com/sac/star-search-form.html** — allows the user to tailor-make observing lists of double stars by constellation and separation.
- **http://ad.usno.navy.mil/wds/** — the Washington Double Star Catalog contains data on nearly 104,000 double and multiple star systems.

Read Chaple's *Deep Sky Monthly* column on all of Scorpius' double stars at www.Astronomy.com/toc.

Secret Sky

by Stephen James O'Meara

Uranus: The *Alice in Wonderland* world

Have amateur astronomers spotted details on the seventh planet, or has it all been an illusion?

"Give your evidence," said the King, "or I'll have you executed on the spot." — *Lewis Carroll,* Alice's Adventures in Wonderland*, 1865*

Through a telescope, Uranus usually appears as a tiny green disk, somewhat flattened, and largely devoid of detail. It's never been a popular target for amateur study. But some tenacious observers over the past century and beyond have occasionally glimpsed subtle bands, zones, and bright and dark spots on the planet.

On January 15, 2010, I received an e-mail from French amateur astronomer Thierry Jolicoeur. Online rumors about Uranus were unusually strong, he said. During the fall of 2009 and the subsequent winter, observers reported seeing weak equatorial bands on the planet — some through apertures as small as 6 inches.

The observations became the subject of much debate. "Most people are highly suspicious to say the least," Jolicoeur said, because other visual observers could not confirm the features. The belts also did not appear on CCD images taken through telescopes as large as 14 inches.

But two veteran planetary observers in the United States — Gene Cross of Fremont, California, and Gene Lucas of Fountain Hills, Arizona — said they had seen similar banding in the mid-1960s, when the planet's equator faced Earth.

Are visual markings on Uranus real?

Weather or not?

Some of the e-mail and Internet forum arguments brought to mind the 1962 movie *Journey to the Seventh Planet*. In that science-fiction thriller, five intrepid explorers rocket to Uranus and land. They expect a barren ice world devoid of life, but instead find it forested with familiar earthlike details. In time, they realize it's all an illusion; whatever is on their minds appears before them. "We've got an *Alice-in-Wonderland* forest here," the mission commander says. "Nothing in front of us is real."

A bright cloud and color bands streak Uranus' surface in this 2005 Hubble Space Telescope image, proving that early amateurs' observations weren't necessarily flights of fancy. NASA/ESA/ M. Showalter (SETI Institute)

Visual observations of Uranus can be the same way because it's a difficult planet to study with confidence. The planet's disk measures only about 4" across when largest. An unstable atmosphere (on Earth) can stir the planet's face into a shimmering soup of artificial detail. It takes skill and patience to catch those rare moments of excellent seeing, when the planet's disk momentarily sharpens.

Our brains try to help our eyes make sense out of any uncertain views. For instance, the brain might dredge up images of details commonly seen on other gas-enshrouded planets, like Jupiter and Saturn. With enough mental persuasion, an observer can organize incomplete visual information on Uranus' tiny disk into familiar details, like belts and zones.

Certainly, mental trickery might explain some of the observations of Uranus in question. But it isn't the only solution.

Bands, zones, and spots

Since T. H. Buffham of Victoria Park, England, recorded the first definite markings on Uranus (two round bright spots) in 1870, nearly all of the well-known visual observers of the 19th- and early 20th-centuries reported features on Uranus.

In a 1975 issue of *Icarus*, Michael J. S. Belton (Kitt Peak National Observatory) and Fred E. Vescelus (Jet Propulsion Laboratory) noted that their historical review of visual and photo-

graphic observations indicates that markings frequently occur on Uranus. "It is therefore surprising," the researchers wrote, "that the best photographic records of Uranus in the visual band [are] entirely featureless, except for the presence of strong limb darkening."

Mike Foulkes, director of the British Astronomical Association's Saturn section, says that, "apart from visual observations, many amateurs have imaged Uranus digitally and the results do appear to be mixed. Some have recorded features, such as a darkening or brightening, but others have recorded nothing."

Nevertheless, as Belton and Vescelus concluded in their paper, it's hard to discount the visual record: "Much direct evidence exists to support the notion that discrete features … exist on Uranus."

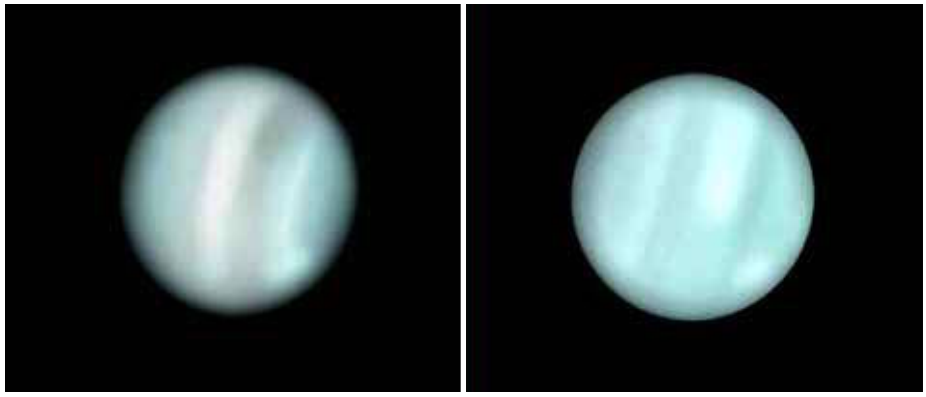
Recognizing these markings, they said, possibly depends on the observer's ability to discriminate color, either by visual acuity or by using filters.

Giving the evidence

When the Voyager 2 spacecraft returned close-up images of Uranus in 1986, it revealed a "featureless cue ball" in visible light. But large Earth-based telescopes and the Hubble Space Telescope have shown that Uranus has changed dramatically since Voyager took its "snapshots" of the then pole-on planet.

More recent visible-light images of an equator-on Uranus brought hope to observers. They showed a bright polar haze, dark bands, bright zones, and multiple bright spots. In 2005 and 2006, for instance, Hubble captured stunning views of a brilliant white spot, dark equatorial bands, a bright equatorial zone, and the first definitive image of a dark spot — all features that skilled visual observers have detected over the past hundred-plus years.

This image of a largely featureless Uranus, which Florida planetary imager Donald Parker took August 23, 2009, shows only prominent limb darkening. Oftentimes, this is all Uranus reveals to observers. Donald Parker



Eight-inch or larger telescopes with magnifications of 350x or more typically produce the best visual studies of Uranus. (At 350x, Uranus appears about the same size as Jupiter at 35x.) Experienced planetary observer David Gray of Durham, United Kingdom, made these color drawings of bands and zones on Uranus based on binocular views through a 16-inch Dall-Kirkham telescope and powers of 365x and 535x July 26, 2004 (left), and November 14, 2009. David Gray

Apparently, dramatic changes do occur on Uranus as the planet's atmosphere responds to seasonal sunlight changes.

To the scopes!

August 2010 begins the year's best observing season for the pale-green planet — by mid-August, Uranus transits around 3 A.M. local time, and by mid-December, it transits around 6 P.M. Don't be discouraged if you don't succeed at first. It's all about time and patience.

As you observe, remember these words by Belton and Vescelus: "Despite the contemporary practice of many planetary scientists to dismiss the efforts of visual observers, the latter have, in fact, a consistently good record when it comes to identifying general domains of contrast on planetary disks."

Heidi B. Hammel, senior research scientist and co-director of research at the Space Science Institute in Boulder, Colorado, also encourages you to keep an eye on the seventh planet. "Though we require the very biggest and best telescopes to resolve the details in the atmosphere of Uranus, the time on these facilities is extremely limited."

"If, however," she continues, "amateurs can alert us to noticeable changes on the planet, then we can activate 'Target of Opportunity' proposals to commandeer the big glass to follow up. The banded patterns on Uranus show up best in the red, but the very interesting and elusive dark spots have the best contrast in the blue, so any and all observations are of interest. Please observe Uranus!"

Good luck, and, as always, let me know how you do by e-mailing me at someara@interpac.net.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

John Tenniel

Evening Stars
by David H. Levy

50 years strong: a national observatory to be proud of

Kitt Peak National Observatory plays an important role for astronomers of all stripes.

On a beautifully sunny late April day in 1963, my family made its first visit to Kitt Peak National Observatory. As we stood inside the massive interior of the McMath Solar Telescope, we saw the Sun's rays reflected off a high "coelostat" mirror to the main mirror far below us, and then back to a smaller diagonal that sent the beam to an observing room beneath us.

"This is how we study the sky," I thought. And at age 15, I wanted to be part of it.

We walked excitedly to our next stop, a guided tour of the newly completed 84-inch telescope. Inside the visitor's gallery, a guide explained its operation. When he was done, he asked if anyone had a question. I certainly did.

Standing up as straight as I could, I asked, "How does an astronomer get to use this telescope?"

The guide glared back. "The telescopes at the National Observatory," he intoned, "are available to *qualified personnel*."

My mother and I stared at each other. Qualified personnel. My bubble burst.

Four years later, I was back, this time under the guidance of Keith Pierce, then associate director of the McMath. As we ascended the steep mountain grade, we saw the observer assigned to the telescope on his way down, having given up, it appeared, due to a little rain. Knowing of my evolving interest in observing the Sun, Pierce suggested that I use one of their telescopes to draw the Sun that day. When we arrived at the telescope, the Sun had emerged from the clouds to form a beautiful yard-wide image atop the instrumentation table. "You're using the largest solar telescope in the world!" Pierce said as I began drawing more than 75 sunspots. Not for nothing was that telescope later renamed the McMath-Pierce Telescope.

Wendee Levy, the author's wife, spent several hours atop Kitt Peak capturing this image of spiral galaxy NGC 6946. Adam Block assisted and combined the various colors together to build this image. Wendee Levy/Adam Block/NOAO/AURA/NSF

Fifty years have passed since the United States established its national observatory atop Kitt Peak in southern Arizona. In 1982, I began observing up there for several days each month. Our team, part of Tucson's Planetary Science Institute, observed asteroids to determine how fast they rotate, and also to understand their shapes and densities. Our telescope was "The Number Two 36-inch" reflector, one of the 16 telescopes that graced Kitt Peak at the time. We worked four or five nights per month. The summer sessions were fun, with long lazy afternoons followed by short, efficient nights. But the 13-hour-long winter nights really allowed us to get the lion's share of our observations.

I particularly recall one spectacular night in 1983. The day had been spotlessly clear, and with the approach of darkness more than a dozen telescopes awakened for a night of celestial marauding. I could barely see the dim outline of our telescope, its little photometer ready to measure the tiny trickles of light from our collection of about a dozen asteroids.

The National Observatory was born in 1958 after the U.S. National Science Foundation reached an agreement with what is now called the Tohono O'odham Nation. A famous tale, probably true, says that what persuaded the Tohono O'odham Reservation to permit the use of their mountaintop for a national observatory was an invitation by Dr. Edwin Carpenter of the University of Arizona in Tucson. He proposed an informal evening of observing at the university's 36-inch telescope. The night's sightseeing focused on the Moon and perhaps also Jupiter.

Apparently, the tribal council was so impressed that an agreement came soon after, allowing astronomers use of the mountain as long as its summit was the site of astronomical research.

I still enjoy every visit I make to our national observatory. Kitt Peak is a wonderful place, and now some of its telescopes are open to amateur astronomers on clear nights. (Visit www.noao.edu/outreach/aop for more information.) This means you might get to spend a night on Kitt Peak, holy ground for American astronomy. May it always enjoy its pristine sky.

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

Could String Theory Be the Long-Sought "Theory of Everything"?

Explore One of Today's Most Thrilling Ideas in Modern Physics with a DVD lecture Series for Non-scientists

One of the most exciting scientific adventures of all time is the search for the ultimate nature of physical reality, a hunt that in the last century has yielded such breakthroughs as Einstein's theory of relativity and quantum mechanics, two theories that radically altered our picture of space, time, gravity, and the fundamental building blocks of matter.

The latest advance in this epic quest is string theory—known as superstring or M-theory in its most recent versions. Based on the concept that all matter is composed of inconceivably tiny filaments of vibrating energy, string theory has potentially staggering implications for our understanding of the universe.

Wouldn't you love to understand string theory at a deeper level than is available from popular articles or even book-length treatments? Aren't you eager to look over the shoulder of a prominent string theorist at work—one who has a gift for explaining the subject to nonscientists and who has created computer-generated images to help make the concepts clear?

The Teaching Company offers just such a guide in Professor S. James Gates, Jr., director of the Center for String and Particle Theory at the University of Maryland. Dr. Gates has presented nearly 100 public talks on string theory.

The 24 lectures in **Superstring Theory: The DNA of Reality** incorporate Dr. Gates's matchless set of graphics, which introduce you to such concepts as hidden dimensions, dark matter, sizzling black holes, and a theory-destroying monster called the tachyon.

Spaghetti Strands

The essence of string theory is that the smallest, most fundamental objects in the universe are not little balls, knocking around like billiards, as had been thought for about 2,000 years. Instead, these small objects are supermicroscopic filaments—like tiny strands of spaghetti—whose different vibrational modes produce the multitude of particles that are observed in the laboratory.

One of the most celebrated features of the string approach is that it predicts more dimensions than the three of our familiar spatial world plus one of time.

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Colossal comet Astronomers announced April 13 at the RAS National Astronomy Meeting that Comet C/2006 P1 (McNaught) is officially the biggest known comet.

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Astronews

Galaxy killer. This multiwavelength image of the galaxy NGC 1275 demonstrates the incredible power of supermassive black holes to affect an entire galaxy, dispersing the materials necessary to make new stars. New research suggests at least one-third of all galaxies went through a similarly deadly phase. A. Fabian (Cambridge)/STScI/NASA

Malevolent black holes may be galaxy killers

A team of astronomers from the United Kingdom wants to add to the already menacing character of supermassive black holes, proposing that they release more than enough energy to shut down a galaxy's star formation, effectively killing the galaxy. Asa Bluck of the University of Nottingham, leader of the research, presented his findings April 16 at the Royal Astronomical Society National Astronomy Meeting.

Before matter disappears down a black hole forever, it swirls around like a basketball rolling around the rim before dropping through the net. Powered by the black hole's enormous gravity, the matter swirls so quickly that it heats up and radiates energy; this swirl is called an accretion disk.

Bluck and his team used space telescopes to image the universe in unprecedented detail, searching for galaxies with high X-ray emissions, a classic signature of accretion disks around black holes. They found that at least one-third of all massive galaxies not only have supermassive black holes, but that their accretion disks also far outshine their host galaxies. The accretion disks put out so much energy, in fact, that cool gas and dust in the vicinity — the basic ingredients for new stars — quickly get blown away.

"We are left with a startling picture of the formation history of massive galaxies," Bluck says, "where dramatic violence in the form of the torrent of radiation from matter falling into black holes leads to the death of galaxies they inhabit." — **BILL ANDREWS**

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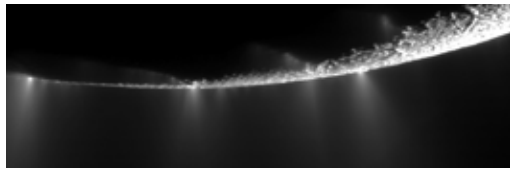
23 Looking into the Rosette nursery

Enceladus' wake of plasma bubbles

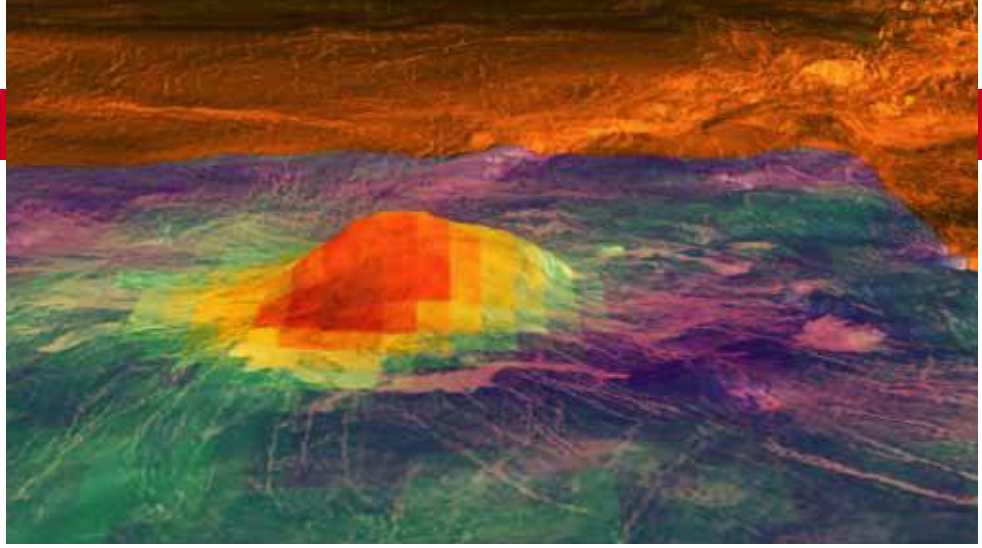
Powerful geysers at the south pole of Saturn's moon Enceladus spew water vapor and water ice into orbit around the planet. This material becomes ionized and forms the bulk of material in Saturn's magnetosphere.

Measurements made by NASA's Cassini spacecraft show that Enceladus soaks up some of these charged particles, or plasma, as they sweep past the moon at around 67,000 mph (108,000 km/h). But the particles flow unevenly, according to scientists at University College London's Mullard Space Science Laboratory.

"Eventually, the plasma closes the gap downstream from Enceladus, but our observations show that this isn't happening in a smooth, orderly fashion," says Sheila Kanani, who reported the results April 15 at the Royal Astronomical Society's national meeting. "We are seeing spiky features in the plasma that last between a few tens of seconds and a minute or two. We think that these might represent bubbles of low-energy particles formed as the plasma fills the gap from different directions." — **RICHARD TALCOTT**



Geysers galore. Scientists counted more than 30 jets erupting from the south polar region in this November 21, 2009, image of Enceladus. NASA/JPL/ SSI



Lava-topped mountain. **The venusian volcano Idunn Mons spans about 125 miles (200 kilometers), and its summit rises 1.6 miles (2.5 km) above the surrounding plains. The color-coding on this radar map shows heat patterns caused by compositional changes that resulted from recent lava flows.** NASA/JPL/ESA

Venus is a volcanic hot spot

Planetary scientists realized some 2 decades ago that Venus' surface possesses relatively few craters. Most researchers suspected that volcanic activity covered up the inevitable impact scars, but no one knew whether this activity took place in the recent past or hundreds of millions of years ago.

Observations from the European Space Agency's Venus Express spacecraft show volcanoes likely erupted within the past few million years, and perhaps remain active today. "Now we have strong evidence at the planet's surface for recent eruptions," says Sue Smrekar of NASA's Jet Propulsion Laboratory, who led the discovery team. The team reported its findings in the April 30 *Science*.

The researchers used the Visible and Infrared Thermal Imaging Spectrometer on Venus Express to peer through the planet's ubiquitous clouds. They targeted three regions that geologically resemble the Hawaiian islands, a well-known volcanic hot spot on Earth.

The team found that these regions have different compositions than their surroundings. On Earth, lava flows react rapidly with atmospheric gases, which changes their composition. The scientists think the same process works on Venus and indicates a lack of surface weathering.

Smrekar says the eruptions and resulting lava flows took place less than 2.5 million years ago, and probably are younger than 250,000 years. On a planetary timescale, that's practically yesterday, and the scientists suspect that Venus remains geologically active. — **R. T.**

ESO/J. Emerson/VISTA

Unveiling the Cat's Paw

Filamentary feline. **The Cat's Paw Nebula (NGC 6334) in Scorpius harbors hundreds of massive stars that recently condensed from this cloud of gas and dust. In visible light, glowing hydrogen typically makes such stellar nurseries appear red. But this view, taken with the European Southern Observatory's (ESO) Visible and Infrared Survey Telescope for Astronomy, reveals near-infrared light emanating from deep within the nebula. Although thick tendrils of dust still block some light, countless stars show through for the first time. ESO released this image April 21. — R. T.**

QUICK TAKES

METEORIC ICE AGE

An upcoming paper in the *Monthly Notices of the Royal Astronomical Society* suggests that Earth suffered thousands of significant meteorite impacts 13,000 years ago, leading to dramatic cooling.

BROWN MIDGET?

A May 1 paper in *The Astrophysical Journal* describes the discovery of a planet-like companion, which seems too young to exist, circling a brown dwarf.

COMMON GROUND

Leicester University's Jay Farihi announced April 13 at the Royal Astronomical Society (RAS) National Astronomy Meeting new evidence that rocky, watery planets similar to Earth may be common in our galaxy.

DISK DRIVE

Epsilon Aurigae's mysterious 27-year eclipses are the result of a disk surrounding a companion star, according to an April 8 paper in *Nature*.

WATER IN THE DUST

Interstellar dust may help explain water's ultimate origin by providing a surface for it to first form on in space, according to Victoria Frankland's April 14 talk at the RAS National Astronomy Meeting.

SUPERNOVA TYPE 3-D

Using "echoes" of light from multiple cosmic reflection sources, a forthcoming paper in *The Astrophysical Journal* describes how to study a supernova from several angles, providing a 3-D perspective.

VIRTUOUS VORTEX

An April 15 paper in *Nature* reports the use of a "vortex coronagraph" to image an exoplanet unusually close to its star, signaling the start of a new technique to find faint planets.

ALL CHARGED UP

On April 12 at the RAS National Astronomy Meeting, University College London scientists announced that they'd made the first direct observations of charged particles using the Cluster spacecraft.

AGE BEFORE BEAUTY

The oldest known martian meteorite turns out to be about half a billion years younger than expected (but not enough to strip it of its title), according to a paper in the April 16 *Science*.

Missing methane. GJ 436b, an exoplanet some 33 light-years away (shown here with its sun in an artist's rendering), shows no signs of the common compound methane. Planetary theories suggest it should abound on the distant world, leaving astronomers stumped for now. NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

Distant exoplanet with missing methane puzzles scientists

Exoplanet GJ 436b may not have a catchy name, but it's starting to become famous just the same. Some 33 light-years away in Leo the Lion, the Neptune-sized gas giant is the smallest planet beyond our solar system any telescope has analyzed. And according to NASA's Spitzer Space Telescope, it holds an even more unusual distinction: It lacks any traces of methane, a compound common to most gas giants.

"It's a big puzzle," says Kevin Stevenson of the University of Central Florida in Orlando, lead author of a study detailing these results in the April 22 *Nature*. "Theorists are going to be quite busy trying to figure this one out."

All our solar system's gas giants harbor methane. On any planet with the common elements hydrogen, carbon, and oxygen and a high enough temperature, the carbon should "prefer" to be in the form of methane, rather than carbon dioxide. But Spitzer showed the opposite is true for GJ 436b.

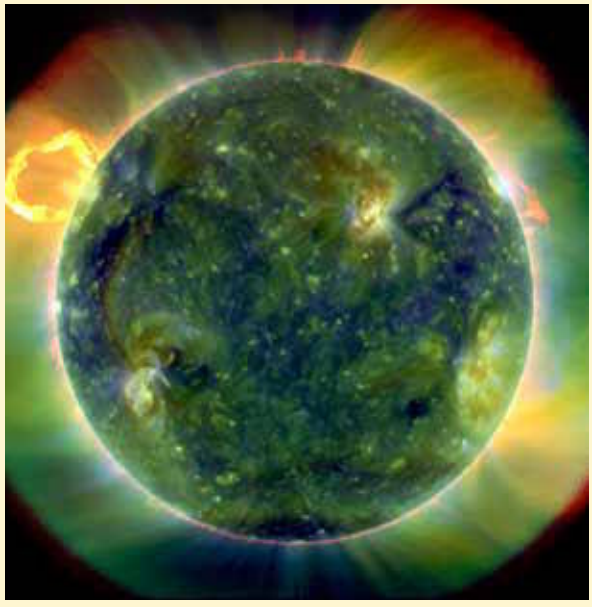
"This type of planet should have cooked up methane," says Joseph Harrington of the University of Central Florida, the principal investigator of the research. "It's like dipping bread into beaten eggs, frying it, and getting oatmeal in the end."

Harrington added that despite the confusion, the Spitzer data provide a better way to eventually learn about "what's really going on" in exoplanets' atmospheres. — **B. A.**

NASA's new eye on the Sun

It didn't take long for the Solar Dynamics Observatory (SDO) to start realizing its vast potential. After rocketing into space February 11, SDO spent 2 months moving into a geosynchronous orbit and activating its instruments. This orbit, which keeps SDO above the same spot on Earth continuously, allows it to both observe the Sun and communicate with the ground 24 hours a day.

On April 21, NASA released the first images and movies beamed back by SDO. Although taken during the spacecraft's commissioning phase, when project scientists were busy testing and calibrating the instruments, the first-light images offered unprecedented views of an active Sun.



Solar blast. An erupting solar prominence (upper left) highlights this view of the Sun taken March 30 by the Solar Dynamics Observatory. Gas temperatures in this false-color, multiwavelength image range from around 110,000° Fahrenheit (60,000 kelvins; shown as red) to more than 1,800,000° F (1 million K; shown as green and blue). NASA/GSFC/SDO AIA Team

Take the prominence that erupted from the solar surface March 30. "We've seen solar prominences before, but never quite like this," says Alan Title of Lockheed Martin, the principal investigator for the Atmospheric Imaging Assembly (AIA). "Some of my colleagues say they've learned new things about prominences just by watching this one movie."

The observatory's main telescope array, AIA contains four telescopes that snap eight full-disk images of the Sun's surface and atmosphere every 10 seconds. The instrument views the Sun in 10 different wavelength bands, from visible light to the extreme ultraviolet, selected to reveal key aspects of solar activity. The ground team can convert these rapid-fire images into high-resolution movies.

If anything, the events of April 8 proved even more impressive. As SDO watched, a decaying sunspot unleashed a minor solar flare. As the shock wave released by this blast raced across the Sun's surface, magnetic loops and other structures rocked back and forth as the wave passed over. Eventually, the shock wave disappeared beyond the Sun's horizon.

But the show wasn't over. Four hours after the initial blast, and some 125,000 miles (200,000 kilometers) away, a massive solar prominence erupted. Title thinks the initial blast and final eruption were related. "As the shock wave swept across the surface of the Sun, it destabilized magnetic fields it encountered en route," he says. "I believe the magnetic underpinnings of the prominence were upset by the wave, and this led to the eruption."

SDO carries two other science instruments: the Helioseismic and Magnetic Imager and the Extreme ultraviolet Variability Experiment. Working together, the three instruments should help solar scientists understand the structure of the Sun's magnetic field, how the field changes, and, ultimately, what generates the field. SDO also will analyze how the Sun's magnetic field stores energy and releases it in explosive solar flares and coronal mass ejections.

Solar physicists have high hopes for what SDO will accomplish during its 5-year mission. Program scientist Lika Guhathakurta of NASA headquarters says, "SDO is our 'Hubble for the Sun.' It promises to transform solar physics in the same way the Hubble Space Telescope has transformed astronomy and cosmology." — **R. T.**

Icy air. The Sun (upper left) shines down on Triton's southern hemisphere in this artist's impression. European researchers have measured carbon monoxide and methane in the atmosphere of Neptune's large moon. ESO/L. Calçad

Summer heat on frigid Triton

At a distance of 2.8 billion miles (4.5 billion kilometers), the Sun doesn't warm Neptune or its moons much. But a little heat can go a long way. A team of European astronomers has discovered higher levels of atmospheric gases surrounding Triton, Neptune's biggest moon, than seen before. The thicker atmosphere coincides with summer in the moon's southern hemisphere.

"We have found real evidence that the Sun still makes its presence felt on Triton, even from so far away," says team leader Emmanuel Lellouch of the Paris Observatory. "This icy moon has four seasons just as we do on Earth, but they change far more slowly." Each season on Triton lasts a little longer than 40 Earth years. Summer began in the moon's southern hemisphere in 2000.

Lellouch and his colleagues used the European Southern Observatory's Very Large Telescope on Cerro Paranal in Chile to analyze Triton's atmosphere. They discovered carbon monoxide and made the first ground-based observations of methane. Triton's average temperature hovers around –390° Fahrenheit (–235° Celsius), but the mercury inches up a few degrees in summer.

As the temperature increases, a thin surface layer of frozen nitrogen, methane, and carbon monoxide sublimates into gas. When the Voyager 2 spacecraft flew past Neptune in 1989 (during southern spring), the atmospheric pressure was a scant 14 microbars — 70,000 times less dense than Earth's atmosphere. Lellouch's team says the pressure now is some 4 times greater. The scientists reported their results online April 7 in *Astronomy & Astrophysics*. — **R. T.**

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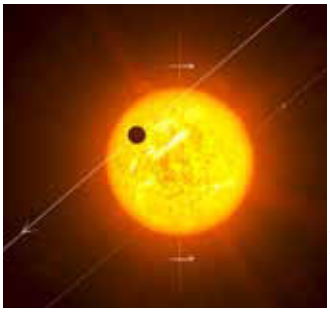
LOFAR launches Europe's Low Frequency Array (LOFAR) has begun mapping the universe; its first images were presented at the RAS National Astronomy Meeting April 13.



ESO/L. Calçada

Backward planets. In this artist's depiction, exoplanet WASP 8b orbits in the opposite direction it "should." Scientists are finding more and more such planets.

More exoplanets found orbiting in "wrong" direction

Recent revelations about the orbits of exoplanets mean astronomers still have a lot to learn about how planetary systems develop. On April 14 at the Royal Astronomical Society (RAS) National Astronomy Meeting, Andrew Cameron of the University of St. Andrews presented his team's findings, which include the discovery of six exoplanets that orbit their star in the opposite direction of the star's rotation.

Scientists had previously known of only one such planet, but the addition of six more suggests the phenomenon could be more than a fluke. "This is a real bomb we are dropping into the field of exoplanets," says Amaury Triaud of the Geneva Observatory, one of the team's leaders.

Because planets likely form in the disk of gas and dust that surrounds a young star, they probably end up orbiting more or less in the same plane and in the same direction as the star's rotation, as in our solar system. New theories now suggest backward-orbiting planets might have altered their original orbit after interactions with other planets or stars.

"The new results really challenge the conventional wisdom," says Cameron. — **B. A.**

Water and organic compounds found on asteroid

Asteroids — chunks of rock orbiting the Sun roughly between the orbits of Mars and Jupiter — are typically associated with the destruction of life on Earth, but new research suggests they may have actually been a necessary component of life.

Andrew Rivkin of the Johns Hopkins University Applied Physics Laboratory and Joshua Emery of the University of Tennessee in Knoxville published a paper in the April 29 *Nature* describing their discovery of water ice and carbon-based organic compounds on the surface of asteroid 24 Themis. This finding supports the idea that asteroids and comets may be the source of water on Earth.

Previously, astronomers considered Themis too close to the Sun at 297 million miles (479 million kilometers) to carry water ice left over from the solar system's origin. But Rivkin and Emery took varied measurements of the asteroid using NASA's Infrared Telescope Facility on seven separate occasions, which consistently showed the infrared signatures characteristic of water ice and carbon-based materials.

"This is exciting because it provides us a better understanding about our past — and our possible future," says Don Yeomans, manager of NASA's Near-Earth Object Program Office. "This research indicates that not only could asteroids be possible sources of raw materials, but they could be the fueling stations and watering holes for future interplanetary exploration." — **B. A.**

BRIEFCASE

Another big scope for Chile

On April 26, the European Southern Observatory selected Cerro Armazones as the site for the planned 42-meter European Extremely Large Telescope. Cerro Armazones is a mountain in the central part of Chile's Atacama Desert and sits at an altitude of 10,400 feet (3,060 meters). — R. T.

Lost lunar reflector shines on

Humans last heard from the Soviet rover Lunokhod 1 September 24, 1971. But recent images from NASA's Lunar Reconnaissance Orbiter showed the rover miles from where researchers expected. On April 22, Tom Murphy of the University of California, San Diego, and his team beamed laser light at the rover and received a signal back from its retroreflector. Scientists use such data (along with that from four other lunar reflectors) to pin down the Moon's distance. — R. T.

Zodiacal light source

The zodiacal light — the pyramidal glow sometimes seen in the west after dusk and in the east before dawn — comes from sunlight reflecting off solar system dust. In the April 20 *The Astrophysical Journal*, David Nesvorny of the Southwest Research Institute in Boulder, Colorado, and his colleagues reported that 85 percent of this dust likely comes from Jupiter-family comets. — R. T.

25 years ago in *Astronomy*

August 1985

In the August 1985 issue of *Astronomy*, Editor Richard Berry explained "How to Plot Star Maps on Your Computer." Creating digital maps on a computer hadn't been possible except with expensive, top-of-the-line equipment, "but relatively cheap technology has made it at last," Berry wrote. "With the advent of the Macintosh, the DEC Rainbow, and various add-on boards for the IBM-PC, computer star maps have finally come home."

These days — when subscribers can visit StarDome Plus at www.Astronomy.com to get a high-resolution view of the sky — it may be easy to forget how difficult such a task once was. Berry also included pixel patterns to map onto stars and even a sample 77-line computer program.

August 2000

10 years ago in *Astronomy*

The August 2000 issue of *Astronomy* featured astronomy writer Govert Schilling's profile of the Very Large Telescope (VLT) and its imminent completion in "Europe's Science Machine." As Schilling explained, hopes were high for the four 8.2-meter telescopes in northern Chile: "It will be an astronomical workhorse for decades to come, providing scientists with record-breaking light-gathering power and a vision much sharper than the Hubble Space Telescope's."

Four 1.8-meter auxiliary telescopes have complemented the main four scopes for about half of the observatory's approximately decade-long life span. Schilling called the almost-ready VLT "an astronomical success story" even before it began making headlines. Luckily, both then and now, its most significant discoveries may still lie in the future. — **B. A.**

Looking into the Rosette nursery

Dusty incubator. About 5,000 light-years away in the constellation Monoceros the Unicorn, the Rosette Nebula and the Rosette Cloud are forming gigantic stars, each up to 10 times as massive as our Sun. This Herschel image, which the European Space Agency released April 12, shows half the nebula and most of the cloud in infrared light. The bright smudges are from the light of massive protostars shining through dusty envelopes; the small spots above center depict protostars of comparable mass to the Sun. — **B. A.**

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How to find planets

The dust clouds that surround other stars can cloak an earthlike planet, but they also can offer tantalizing clues to a planet's presence.

by Marc J. Kuchner and Christopher C. Stark

Imagine standing on the surface of Tau Ceti c, a hypothetical terrestrial planet with a humble but technologically advanced civilization. You peer at images from a large telescope the inhabitants have built to search for other worlds that might harbor life. A nearby G2 main sequence star comes into view.

Powerful systems for actively controlling the telescope optics switch on and a coronagraph slides into place to block the star's light. You and the alien scientists suck in your breath, hoping to see a pale blue dot orbiting the star, perhaps another habitable planet like your own.

Wait — is something wrong with the telescope? The star's there all right (you guessed it, it's our Sun), but where are the planets? And what is that bright fuzzy cloud all around the star where the planets should be?

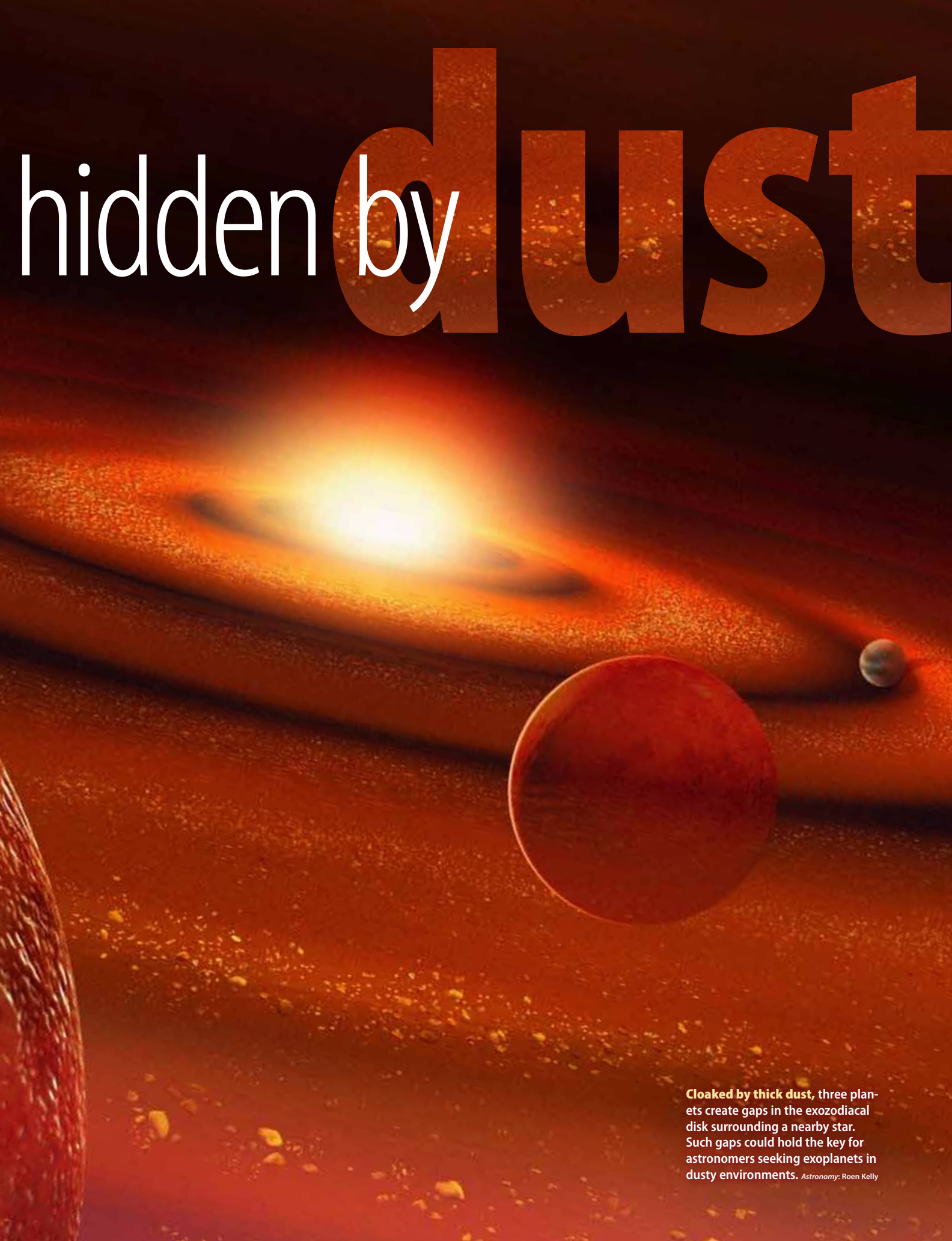
The astronomers around you shrug their shoulders and tell you the bad news: They have run into a cloud of "exozodiacal dust."

That is a story Earth astronomers have been telling themselves for the past few decades. It doesn't matter if you are searching for Earth from Tau Ceti c or trying to observe other worlds from Earth, the story is the same. If you try to image an earthlike planet around another star, you probably will first run into exozodiacal dust — the scourge of planet-hunters everywhere. What is this stuff, and what can astronomers do about it?

A dusty mess close to home

Dust fills our solar system. The sources of these little bits of sandy grit are legion. As comets approach the Sun, they warm up and jets burst from their surfaces, leaving behind dusty trails. Asteroids collide with one

hidden by dust



Cloaked by thick dust, three planets create gaps in the exozodiacal disk surrounding a nearby star. Such gaps could hold the key for astronomers seeking exoplanets in dusty environments. *Astronomy:* Roen Kelly

The zodiacal light glows in the shape of a huge pyramid above Earth's horizon. The light arises from sunlight reflecting off dust grains in our solar system's zodiacal cloud. Rob Ratkowski

The battered surface of Eros testifies to the innumerable impacts that take place in and near the asteroid belt. Debris from such collisions helps litter the solar system with dust. NASA/JHUAPL

another, producing families of new asteroids and lots more dust. In the outer solar system, distant Kuiper Belt objects release dust when they collide.

All these activities add up to a big, beautiful mess. A vast cloud of dust, the "interplanetary dust complex," stretches from the Sun's corona to the Kuiper Belt and beyond. Astronomers call the inner part of this dust cloud, from the Sun to the asteroid belt, "zodiacal dust." A similar cloud of dust around another star goes by the name "exozodiacal dust."

The funny thing about our solar system's zodiacal dust is that if you were zooming through the thickest part of the cloud, you might not even notice it. The dust grains spread out so much that even the cloud's core forms a vacuum better than the best laboratories on Earth can achieve. But if you were to view the cloud from far away, so you could see all the dust at once, it would look much different. With all that dust sparkling in the sunlight, the entire zodiacal cloud would appear brighter than Venus.

From a dark site, you can see zodiacal dust with your naked eyes after sunset or before sunrise. It appears as a big triangle of light centered on the constellations of the zodiac (hence the name zodiacal dust). A patch of our zodiacal cloud about 0.1 astronomical unit across (or one-tenth the distance between the Sun and Earth) glows just as bright as our own planet. That's the bright haze that the astronomers on Tau Ceti c stumbled upon when trying to locate Earth.

Marc J. Kuchner *and* **Christopher C. Stark** *study exozodiacal dust clouds working from the Exoplanets and Stellar Astrophysics Laboratory at NASA's Goddard Space Flight Center in Greenbelt, Maryland.*

Into the great unknown

The two of us heard the exozodiacal dust story many times from our colleagues and wondered: Should we give up on imaging an earthlike planet? Is the problem just too hard to deal with?

Astronomers know roughly how much zodiacal dust the solar system contains. It's about the amount of dust you would get if you took a single comet some 10 miles (16 kilometers) across, ground it into dust grains from 1 to 100 micrometers in size, and spread them out along the plane of the solar system between the Sun and the asteroid belt. We sometimes refer to this amount of dust as "one zodi."

How much dust exists around other nearby stars is harder to figure. Although exozodiacal dust may be bright compared with an earthlike planet, it's still hard to see. It often takes the newest technological tricks just to spot it.

Most of what astronomers know about exozodiacal dust comes from measuring the brightness of nearby stars at infrared wavelengths. Dust, which absorbs starlight and reradiates it in the infrared, shows up as excess radiation. This technique is notoriously insensitive because it can detect exozodiacal dust clouds only if they have at least a few hundred zodis worth of dust.

On the prowl for dust

So, how much exozodiacal dust do nearby Sun-like stars really have? We went to the Keck telescopes, located atop Hawaii's Mauna Kea, to find out.

Sitting on a mound of red volcanic rock, the two 10-meter Keck telescopes form the first stage of the Keck Interferometer Nuller. This new gadget is designed especially to see faint objects, like dust clouds, next to bright objects,

like nearby stars. The Nuller incorporates lots of cutting-edge optical technology. The big scopes feed light through a succession of mirrors that vibrate to compensate for changes in atmospheric conditions. A system of lasers measures the distances between the mirrors to pinpoint their positions to within a fraction of a micrometer.

We started using the Keck Interferometer Nuller by pointing it at 51 Ophiuchi, a star we already knew had some dust around it based on previous surveys. We figured this would be a good test for the new instrument.

The Moon was up, but we didn't mind because we were looking for mid-infrared radiation (the Moon shines mostly in optical light). One at a time, the twin adaptive optics systems locked onto the star. The beams of light from the two telescopes shot down into a black metal box in the basement of the mountaintop observatory, nearly 14,000 feet above sea level. Inside the box, specialized optics combined the light from the two telescopes, removing (or "nulling") the star's light and enhancing the light from the region right next to the star.

The new gadget worked. The beams of light from the two scopes met each other and canceled the starlight. We caught a little bit of thermal radiation from the dust surrounding the star. When we combined our data on 51 Ophiuchi with older observations, we realized that this star doesn't have just one cloud of dust around it, but two — an outer belt of small dust grains that extends to where this system's Kuiper Belt might be, and an inner belt that looks like exozodiacal dust.

We're now working on a larger survey of stars with the Nuller. We are looking at stars with no known exozodiacal dust to get a better idea of how common it is around the stars where we'd like to search for earthlike planets. At the same time, other observatories, including the new Large Binocular Telescope on Mount Graham in Arizona, are working to develop new nulling interferometers that promise to be even more sensitive than the Keck Interferometer Nuller.

A mammoth dust tail erupts from the nucleus of Comet C/2006 P1 (McNaught). Dust ejected by comets creates a significant chunk of our zodiacal cloud. Mike Salway

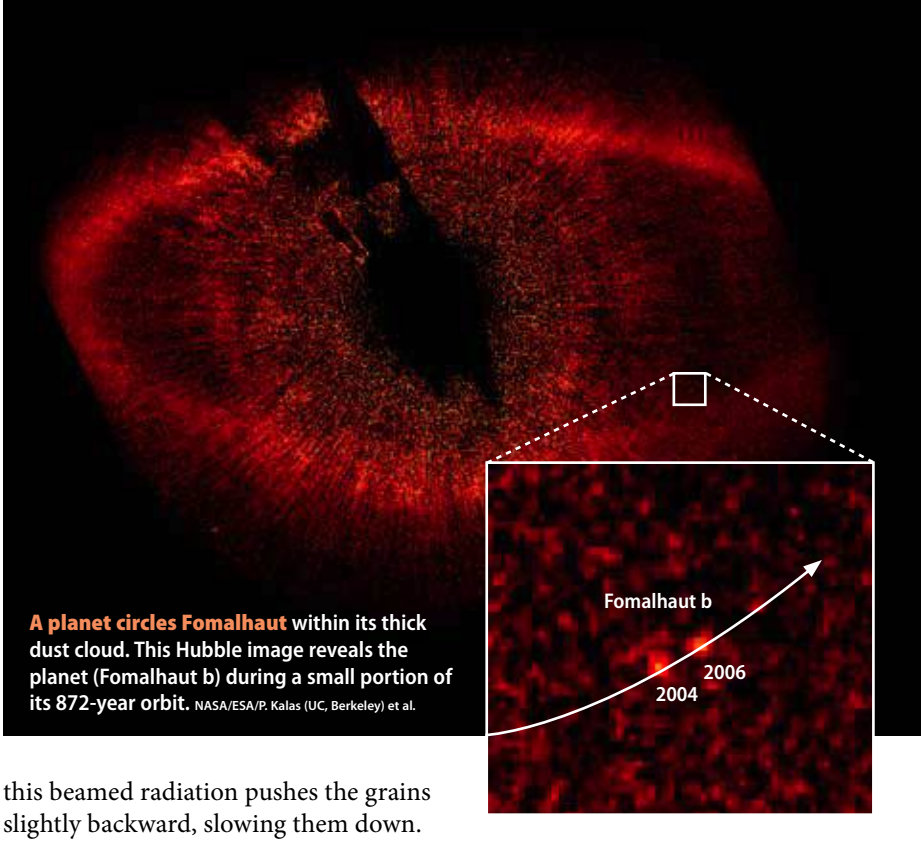
The twin Keck telescopes atop Mauna Kea have detected light from dust disks around other stars. The two scopes work together to cancel a star's light and reveal the faint disks. Richard Wainscoat

Chasing bright spots

Measuring the amount of exozodiacal dust around nearby stars is a vital first step. But astronomers need to understand another important puzzle about these dust clouds.

In 1993, Stan Dermott of the University of Florida and his colleagues were studying maps of our solar system's zodiacal dust, pondering a strange phenomenon. If you stand on Earth and look along its orbit, either in front of or behind our planet, the zodiacal dust cloud glows a little brighter. The extra brightness seems to follow us around the Sun all year long. Dermott's team wanted to find out what causes these bright spots.

Most of the dust grains in the zodiacal cloud near Earth are spiraling slowly into the Sun. Blame a phenomenon known as Poynting-Robertson drag. This drag occurs when a grain radiates away the solar energy it receives. Because the grains orbit the Sun at about 10 miles per second (16 km/sec), roughly 0.01 percent the speed of light, the radiation they emit is beamed according to the laws of special relativity. The force from



A planet circles Fomalhaut within its thick dust cloud. This Hubble image reveals the planet (Fomalhaut b) during a small portion of its 872-year orbit. NASA/ESA/P. Kalas (UC, Berkeley) et al.

this beamed radiation pushes the grains slightly backward, slowing them down.

Based on earlier research by Al Jackson and Herb Zook of NASA's Johnson Space Center in Houston, Texas, Dermott thought this gradual spiraling-in process might play a role in causing the bright spots. As the grains spiral around the inner solar system, they encounter planets, including Earth. Whenever the dust grains pass by a planet, they get a little gravitational tug. Depending on the exact orbits of the grains, these tugs can add up.

Dermott and his co-workers realized that the dust probably spiraled right into special orbits where the tugs from Earth added up to a big deal. In these orbits, called "mean-motion resonances," Earth's gravitational pull counteracts the Poynting-Robertson drag force. This temporarily halts the grains' death spirals and causes them to pile up in a ring around the Sun.

In other words, the zodiacal dust cloud bears Earth's signature: a ring around the Sun with a radius of 1 astronomical unit that matches Earth's orbit. And that's just for Earth, a relatively small planet on a tidy circular orbit. Perhaps extrasolar planets could create similar rings around their host stars. If they do, how would that affect attempts to directly image earthlike extrasolar planets?

Calculating the dusty odds

Answering that question requires a computer. A big one. Fortunately, we work at NASA's Goddard Space Flight Center, home to one of the fastest supercomputers available for scientific computation — the 14,848-core Discover cluster.

Using the Discover cluster, we started making models of extrasolar planetary systems to see what other kinds of planets might do to dust clouds. To make these models, we used the computers to trace the orbits of individual dust grains as they spiral around and interact with planets. By tracking enough grains of different sizes and launching points, we built synthetic pictures of entire clouds.

Our models immediately showed that the extrasolar planets we know about can completely reshape an exozodiacal dust cloud. And these planets forge patterns much more dramatic than Earth's ring in the zodiacal dust.

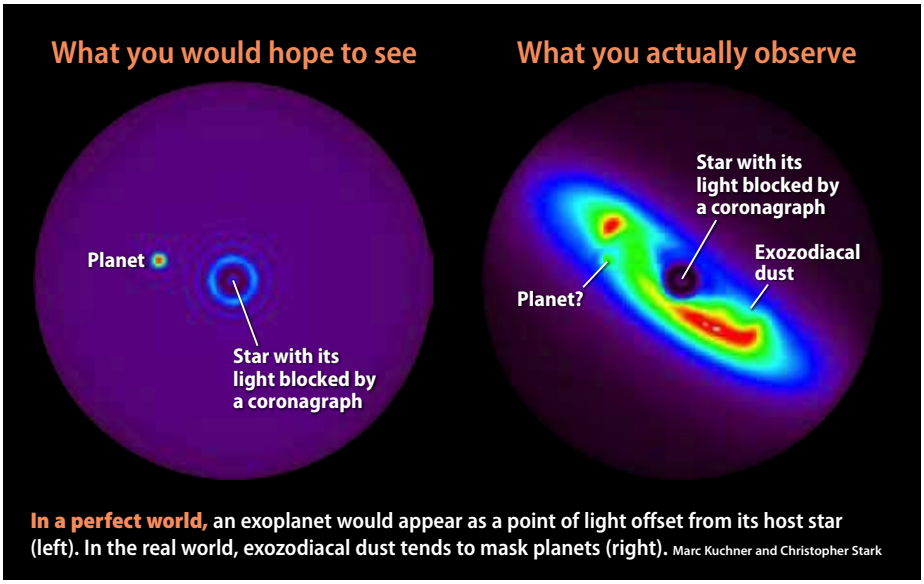
These rings tend to be thick and clumpy. A gap in the ring points to the planet's current location, and asymmetries in the clumps indicate the direction of the planet's orbital motion.

This could be disastrous for planet-hunters. If dust structures and clumps commonly inhabit exozodiacal dust clouds, how can astronomers tell the dust clumps from planets? On the other hand, these dusty rings could prove to be a planet-hunter's best friend. Maybe they can help point the way to previously unseen planets.

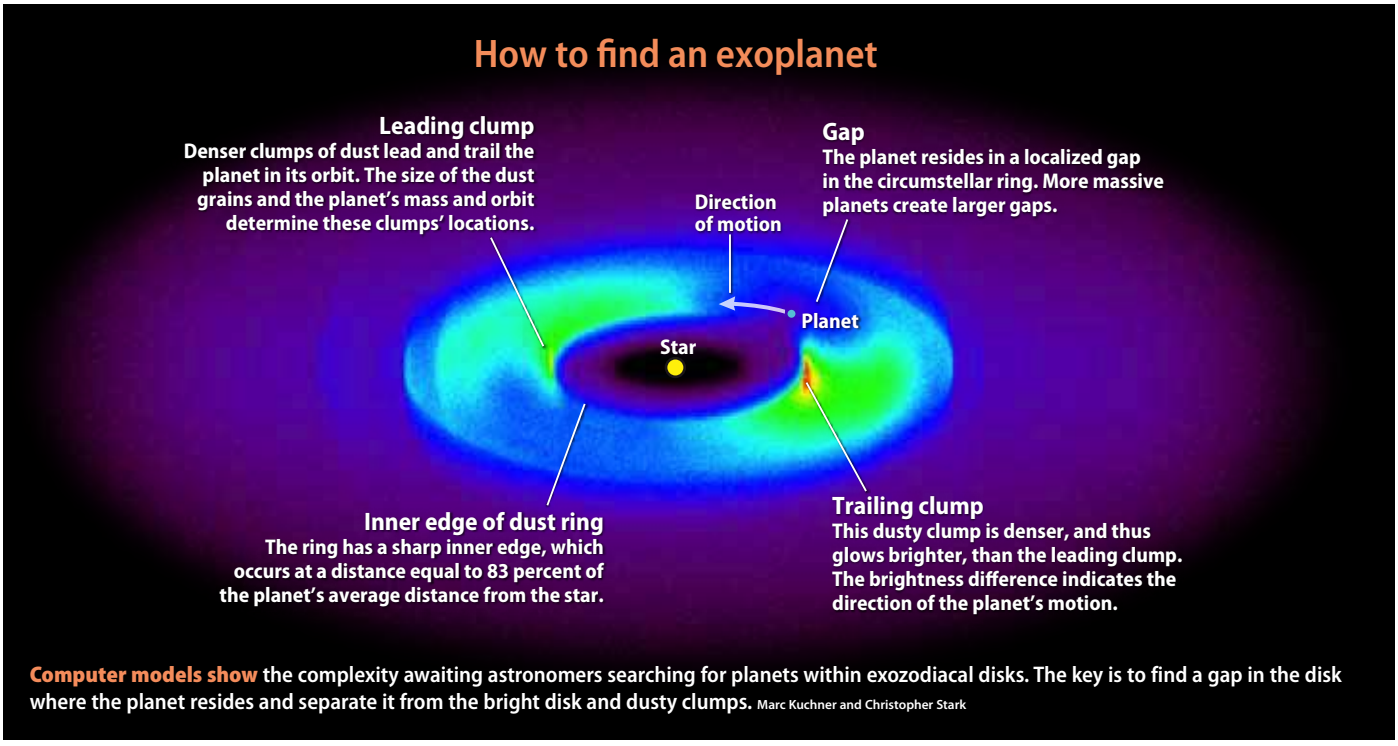
That's more or less what happened when astronomers looked at Fomalhaut, a main sequence star located just 25 light-years from Earth. Fomalhaut ranks among the 20 brightest stars in the sky and stands out on autumn evenings.

Images of Fomalhaut taken with the coronagraph on the Hubble Space Telescope's Advanced Camera for Surveys show a narrow ring surrounding the star. This dusty ring is similar to exozodiacal dust but located much farther from the star, so it's easier to see. There's also a heck of a lot more dust around Fomalhaut than in our solar system.

University of California at Berkeley astronomer Paul Kalas and his colleagues noticed that Fomalhaut's ring is not quite centered on the star. Instead, the ring seems to follow an elliptical path, like the elliptical orbit of a planet. They took



In a perfect world, an exoplanet would appear as a point of light offset from its host star (left). In the real world, exozodiacal dust tends to mask planets (right). Marc Kuchner and Christopher Stark



Computer models show the complexity awaiting astronomers searching for planets within exozodiacal disks. The key is to find a gap in the disk where the planet resides and separate it from the bright disk and dusty clumps. Marc Kuchner and Christopher Stark

the hint and stared at Fomalhaut with Hubble for many more hours.

After years of observations, Kalas' team discovered what seems to be a planet orbiting Fomalhaut just inside the dusty ring where they guessed it would be. The spectacular images were among the first ever made of an extrasolar planet. And all because of a ring of dust.

With the story of Fomalhaut firmly in mind, we are creating a library of computer models of exozodiacal clouds sculpted by planets. We hope that one day coronagraphs and interferometers will become powerful enough to image extrasolar Earths.

If the images are cloudy with the light from exozodiacal dust, we will take the images from these instruments and compare them with our library of models. If they match, we will know a planet lies within the cloud, imprinting its signature into the dust. From the dust patterns we see, we expect to be able to determine roughly the planet's mass and the size and eccentricity of its orbit. We will learn to read the signs of planets in the dust.

A collision with reality

End of story, right? If only we could be so lucky. As we continued working on our models, we discovered one more effect we needed to worry about: collisions between dust grains.

Dust grains in our solar system (which contains 1 zodi worth of dust) seldom collide with one another. But when they do, it packs a wallop. A collision between two grains orbiting near Earth typically would occur at a speed of several thousand miles per hour. This is 10 times faster than a bullet from an M16 rifle and fast enough to shatter or vaporize the particles.

In a cloud with 10 or 100 zodis worth of dust, collisions happen often enough that we can't ignore them. If the grains start colliding with one another before they spiral into the star, the collisions will change the cloud's shape.

Handling these collisions in our computer models at first seemed like a daunting task. These clouds contain more than a billion trillion dust grains. It takes a lot of computer time simply to follow the orbits of enough grains to model a whole cloud. But picture all those grains colliding with one another. Just keeping track of what has smashed into what easily could slow down the computer until it becomes useless.

We had to come up with a new method called the "collisional grooming" algorithm to handle these collisions. The algorithm uses a trick — instead of keeping track of each and every collision between dust grains, we keep track of how streams of particles interact with one another statistically. This won't help, of course, if we need to know where a particular grain is at any given moment. But we're just interested in predicting what the whole cloud of particles would look like from a few light-years away.

Once our models started keeping track of collisions in dust clouds with 10 or 100 zodis worth of dust, a wealth of new complexities emerged. As the collision rate increased, the rings changed shape and the clumps became fainter. In general, the pattern looked less like a clumpy dust cloud and more like the belt of asteroids that produced the dust.

We're working to include these effects in our library of models. Once we understand these new phenomena, we will be ready to interpret images of dust clouds that have 1 zodi, 10 zodis, or 100 zodis of dust. We'll be able to handle planets stirring the dust that are as small as Mars and as big as Jupiter.

It may be awhile before astronomers can image terrestrial planets around other stars and see if they have water and oxygen, as Earth does. It might take new technologies now under development to make this enterprise affordable. In the meantime, the exozodiacal dust clouds are out there, still reluctant to reveal the secrets within.

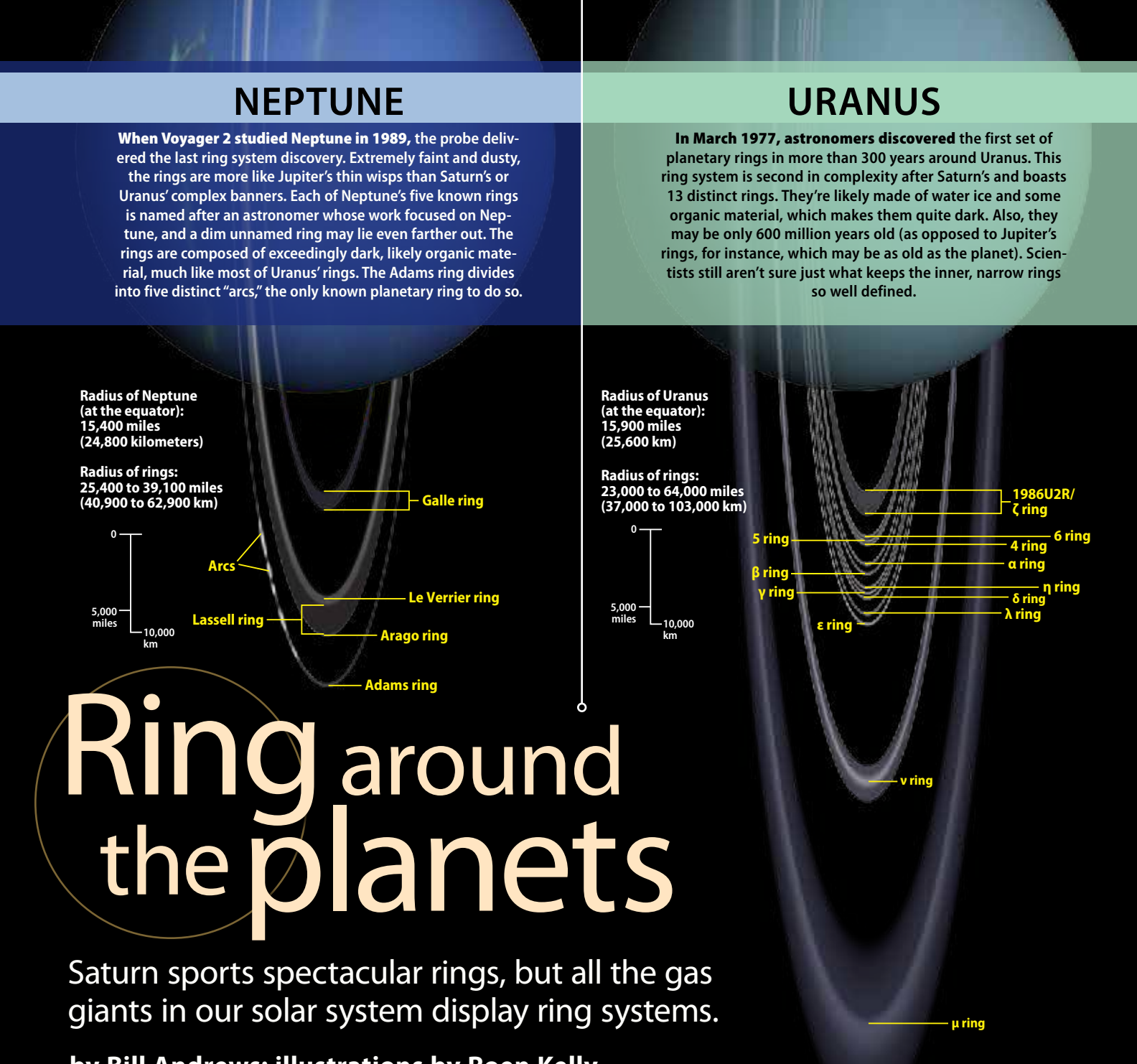
Read about zodiacal dust in ancient Egypt at www.Astronomy.com/toc.

NEPTUNE

When Voyager 2 studied Neptune in 1989, the probe delivered the last ring system discovery. Extremely faint and dusty, the rings are more like Jupiter's thin wisps than Saturn's or Uranus' complex banners. Each of Neptune's five known rings is named after an astronomer whose work focused on Neptune, and a dim unnamed ring may lie even farther out. The rings are composed of exceedingly dark, likely organic material, much like most of Uranus' rings. The Adams ring divides into five distinct "arcs," the only known planetary ring to do so.

URANUS

In March 1977, astronomers discovered the first set of planetary rings in more than 300 years around Uranus. This ring system is second in complexity after Saturn's and boasts 13 distinct rings. They're likely made of water ice and some organic material, which makes them quite dark. Also, they may be only 600 million years old (as opposed to Jupiter's rings, for instance, which may be as old as the planet). Scientists still aren't sure just what keeps the inner, narrow rings so well defined.



Ring around the planets

Saturn sports spectacular rings, but all the gas giants in our solar system display ring systems.

by Bill Andrews; illustrations by Roen Kelly

Anyone familiar with the night sky or our solar system knows about the bright, beautiful ring system encircling the planet Saturn. Far fewer know about the rings around the other gas giants — Jupiter, Uranus, and Neptune — and for good reason: Until 33 years ago, they were completely unknown.

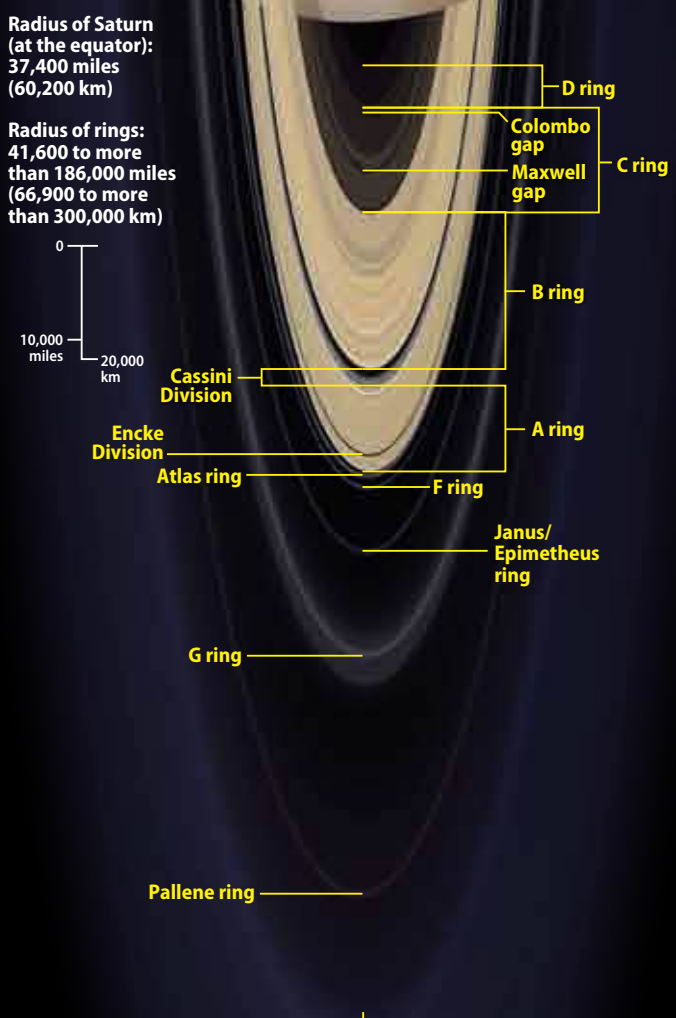
While none can compete with Saturn's dazzling rings, the other planetary systems still make striking images. With the advent of better telescopes and the Voyager missions, scientists learned about these rings one system at a time, and in greater and greater detail. What seemed at first flat and solid around Saturn turned out to be lumpy and gritty; where once only five rings existed around Uranus, there turned out to be 13. Many of the mechanisms behind some of the rings' properties still remain under debate.

Planetary rings have always been accidental discoveries, and some scientists suspect such phenomena might even form around objects other than gas giants, including Earth itself. They've fascinated and mystified for as long as we've known about them, and odds are that the more we learn about the rings, the more they'll surprise us.

Assistant editor **Bill Andrews** *used to wish he could be the first person to walk on Saturn's rings. Then he learned a little more about them.*

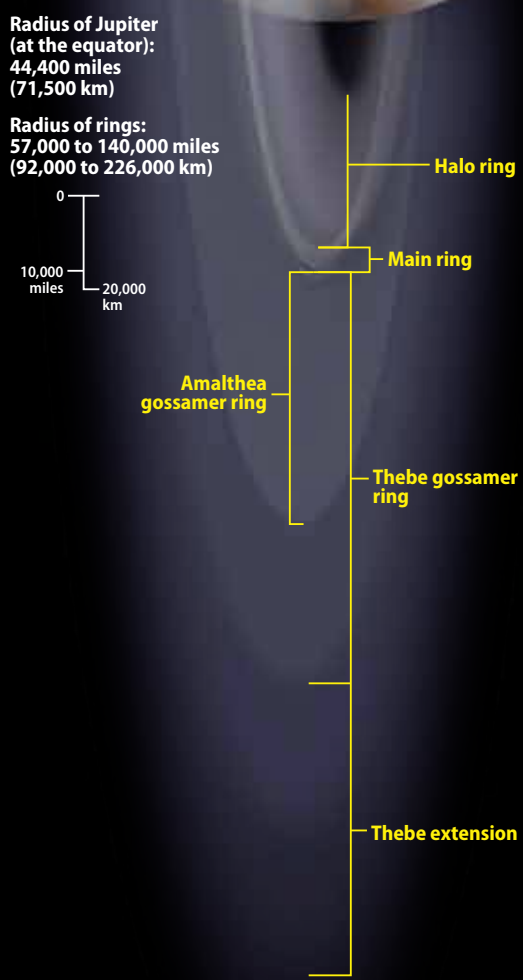
SATURN

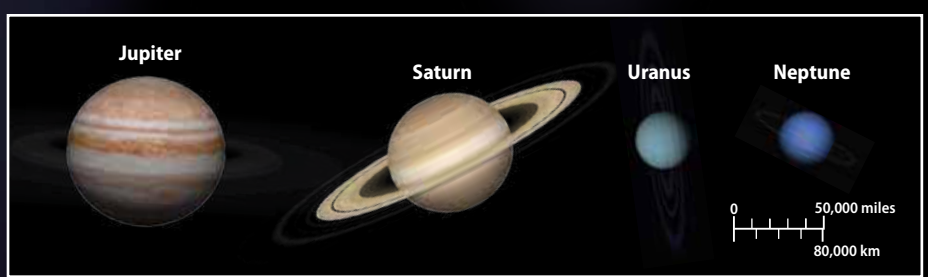
Saturn's rings make for a familiar sight, serving as an emblem not just for ring systems but for exotic planets in general. When Galileo first saw the rings in 1610, he had no idea what they were; it took a young Christiaan Huygens to identify the strange "ears" as a system of rings around the planet in 1655. The rings are made of dust and water ice particles of various sizes, from microscopic to yards across, and they even possess an incredibly thin atmosphere of oxygen. Their complicated structure is likely due to the gravitational effects of Saturn's moons.



JUPITER

The jovian ring system, despite belonging to the largest planet, is in fact the simplest of the four systems. The space probe Voyager 1 discovered the rings in 1979, although they are technically visible from Earth using the biggest telescopes. The Main ring, the brightest and thinnest component of the system, is the most identifiable of Jupiter's rings and is made of dust and slightly larger particles. The inner Halo ring and the outer two gossamer rings are much fainter and made entirely of dust.





The four gas giants, Jupiter, Saturn, Uranus, and Neptune, shown here to scale with each other, all support ring systems. Only Saturn's, however, are easily visible from a distance. Note also the variety of inclination, or tilt, each exhibits, especially Uranus'. *Astronomy*: Roen Kelly, from Lunar and Planetary Institute

Astronomy magazine

10 crazy ideas from astronomy's past

Comet Pills were the brainchild of two Ohio men who sold them in 1910 when Halley's Comet appeared. This 1986 version pokes fun at that scam. Strasenburgh Planetarium

Some theories excel at explaining the universe. Others, like the ones here, are entertainingly ridiculous. **by Michael E. Bakich**

Throughout astronomy's storied history, many hypotheses (proposed explanations for observable phenomena) have appeared. Some have been sheer genius. Others, although couched in the language of science and put forth by well-meaning theorists, have not endured the test of time. Looking back, some may call those ideas crazy. I present 10 of my favorites here, in no particular order. I think you'll agree that while some have the air of credibility, others are Looney Tunes wacky.

Michael E. Bakich *is an* Astronomy *senior editor who loves astronomy's colorful history.*

1 Warning: poison! Do not breathe

A little bit of scientific knowledge can be scary. In 1910, Halley's Comet approached to within 14 million miles (22.5 million kilometers) of Earth. Our planet actually passed through the comet's tail May 18.

The comet that year recorded many firsts. It was the first comet astronomers photographed extensively. It also was the first one researchers examined spectroscopically. And that led to one crazy idea.

On February 8, 1910, *The New York Times* reported that astronomers at Yerkes Observatory in Williams Bay, Wisconsin, had identified cyanogen (a cyanide byproduct) as a component within the tail of Halley's Comet. Indeed, the story's headline, "Comet's Poisonous Tail," pretty much sums up the text.

In the story, French astronomer Camille Flammarion claimed the cyanogen "would impregnate the atmosphere and possibly snuff out all life on the planet."

Today, one newspaper story wouldn't carry much weight, but what followed in 1910 was mighty strange. Unscrupulous vendors marketed comet pills (see the image, above left), gas masks, and other items they claimed would protect individuals from the harmful effects of the gas. And in the 3 months between when the story appeared and when Earth passed through the comet's tail, the "protective" items sold like hotcakes.

Other astronomers rushed to reassure the public. Even Percival Lowell knew this idea was crazy. He gave several interviews and lectures in which he (correctly) said the gas in the tail of Halley's Comet was much too thin to have any effect on Earth's populace.

2 What lies beneath?

In 1818, American John Cleves Symmes, Jr., suggested that Earth was not solid. Rather, he proposed that our planet consisted of a series of at least four concentric, hollow spheres. The main one was about 800 miles (1,300 km) thick. Furthermore, he said there were 1,400-mile-wide (2,250 km) openings at both poles.

Symmes proposed an expedition to the North Pole hole, but the trip never materialized. In 1826, one of his followers, James McBride, authored *Symmes' Theory of Concentric Spheres*. Other books and sub-theories followed.

Earth is not hollow, nor are any of the planets, moons, asteroids, or stars. The material that forms massive objects compresses because of gravity. Also, the material in Earth's crust is not strong enough to support a hollow shape against the force of gravity. If Earth were hollow, its mass would be much lower, its surface gravity would be less, and I'd feel better whenever I stood on a scale.

3 Steady as she goes

Few theories have had the intellectual firepower behind them like the Steady State theory did. In 1948, three of astronomy's luminaries — Hermann Bondi, Thomas Gold, and Fred Hoyle — introduced this idea as an alternative to the Big Bang theory, which addresses how the universe began. In the following years, many other scientists joined them.

The Steady State theory acknowledges that the universe is expanding, but it also states that the cosmos doesn't change its appearance over time. It looks the same now as it always has. Astronomers refer to this characteristic of the Steady State theory as the perfect cosmological principle.

For this theory to work, new matter must pop into existence. From where? Ah, that's the crazy part: from nowhere. To keep space looking the same for infinity, proponents imagine that every 1 billion years, one atom of hydrogen "appears" for each cubic meter of space.

Within 2 decades, the Steady State theory had followed the stegosaurus into extinction. The theory's death blow came in 1964 when two Bell Laboratories radio astronomers, Arno Penzias and Robert Wilson, discovered the cosmic microwave background radiation that the Big Bang theory accurately predicts.

4 Intelligent life on Mars

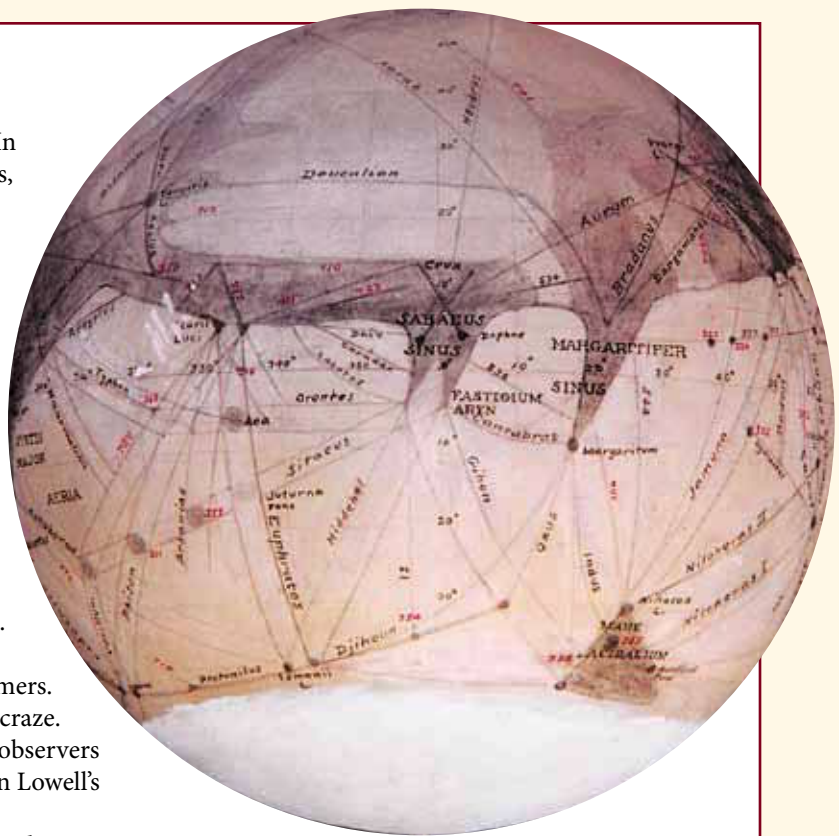
The 1877 opposition of Mars was a scientific bonanza. In America, Asaph Hall discovered Mars' two small moons, Phobos and Deimos. In Italy, Giovanni Schiaparelli observed and sketched the planet. He named features and recorded many straight lines. Schiaparelli dubbed the lines *canali* (Italian for "channels" or "grooves"). English speakers mistranslated the word "canals."

The possibility of canals built by intelligent life on Mars enthralled wealthy Bostonian Percival Lowell. He set up an observatory overlooking Flagstaff, Arizona. In 1895, Lowell published his first book, *Mars*. He made much of the canal network's planet-girdling geometry, writing that "[a] mind of no mean order would seem to have presided over the system we see." Lowell believed Mars was a dying world and that martians built the canals to stave off the encroaching desert.

The public enjoyed Lowell's theories and bought his books in large numbers, but his ideas horrified astronomers. They worked to rein in the maverick and end the canal craze.

The 1909 martian opposition did just that. Credible observers from around the world, using new telescopes larger than Lowell's 24-inch refractor, saw more details on the Red Planet.

Italian astronomer Eugène Antoniadi had charted canals in 1894 using small telescopes. In September 1909, he studied Mars with the 33-inch refractor at Meudon Observatory in Paris and saw no canals. Antoniadi reported his results by letter to Percival Lowell, who remained unmoved. From his Flagstaff hilltop, Lowell continued to map martian canals until his death in 1916.



Percival Lowell's Mars displayed straight-line features he was sure were canals a dying race of intelligent beings constructed to move water across the planet's face. Linda Hall Library of Science, Engineering, and Technology

The Meteoritic Hypothesis **by Sir Joseph Norman Lockyer put forth his wacky theory.** Michael E. Bakich library

5 A Sun full of stones

Consider the strange case of English astronomer Sir Joseph Norman Lockyer. In 1868, his use of spectroscopy led to the discovery of helium in the Sun. The following year, he established the science journal *Nature*. But in 1890, he wrote a book that put forth a crazy idea.

In the preface to *The Meteoritic Hypothesis*, Lockyer summed up his book: "The work now considered follows logically upon researches which suggested that many solar phenomena might owe their origin to the falls of meteoritic masses upon the sun's surface."

Lockyer proposed that comets and meteors fueled the Sun's massive energy output. But he went far beyond that statement. Lockyer explained the glow of nebulae, the aurorae, even variable stars by his meteoritic hypothesis. He wrote that the light output of cosmic bodies varies because of "the interpenetration of meteoritic sheets or streams."

Lockyer also wrote: "It may be that I should have added a final chapter, giving an account of the objections raised to the views here expressed. I have not done this because such objections as have been formulated have dealt only with small details of no fundamental importance for the hypothesis as a whole." Honestly, Sir Norman, one chapter would hardly have been enough.

6 Vulcan before Spock

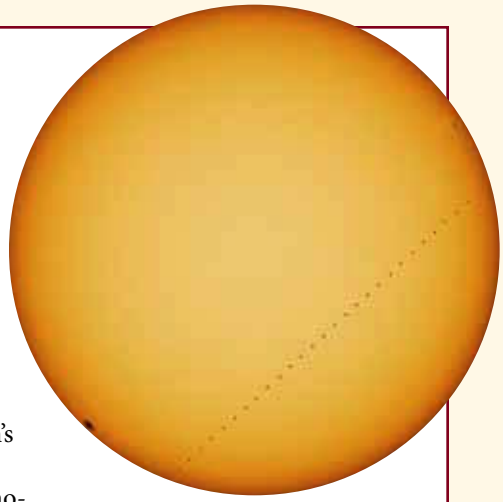
Believe it or not, this crazy idea has nothing to do with *Star Trek*. In 1859, French astronomer Urbain Jean Joseph Le Verrier studied Mercury's motion. He found that the planet's closest approach to the Sun advances by a small amount each orbit. The predicted value differed from his observed value by 43 arcseconds per century.

Le Verrier explained the difference by theorizing the presence of a small planet he called Vulcan. He placed this world inside Mercury's orbit. Le Verrier had predicted Neptune's position in 1846, so astronomers took him seriously — at first.

In 1859, French amateur astronomer Edmond Lescarbault claimed to have seen a transit of the hypothetical planet. He had noticed a small, moving black dot on the Sun through a 3.75-inch refracting telescope. He guessed he was observing a transit of a previously undiscovered body.

Based on Lescarbault's observation, Le Verrier computed Vulcan's orbit as 19 days and 17 hours. He predicted future transits, but when nobody saw them, he changed Vulcan's orbital parameters several times.

Le Verrier died in 1877, and astronomers stopped looking for Vulcan. Finally, in 1915, Einstein's general theory of relativity explained that the difference between theory and observation of Mercury was due to the Sun's gravitational field.



This time-lapse series **shows Mercury transiting (moving across) the Sun's face. In the latter half of the 19th century, astronomers hoped to see a similar transit of the intramercurial planet Vulcan.** Bill Hood

And the winner is …

On December 17, 1900, the French Académie des Sciences announced a 100,000-franc prize called the Prix Guzman (Guzman Prize). The sponsor, Clara Gouget Guzman, donated the money in honor of her son, Pierre. The award would go to "the person of whatever nation who will find the means within the next ten years of communicating with a star and of receiving a response."

Because many people (and some scientists) believed Mars had life, communicating with the Red Planet would not win you the prize. The Academy awarded the prize to the crew of Apollo 11 October 29, 1969.

7 Light's shifty journey

In the 1920s, American astronomers Edwin Hubble and Milton Humason discovered that light from distant objects shifts to the red end of the spectrum proportional to their distances. This relationship, called Hubble's Law, proves the universe expands. But not all astronomers accepted it.

Swiss-born American astronomer Fritz Zwicky rejected the idea. In 1929, he suggested that redshift occurs because light loses energy as it travels through space — a kind of drag effect.

In his theory, photons transferred their momentum to celestial objects or other photons. Such a decrease in energy would increase the light's wavelength, producing the observed redshift that, incidentally, increased proportionally with the distance of the source. In the early 1930s, American physicist Richard Tolman dubbed this the "tired light" theory. Most astronomers just call it crazy.

8 Just passing through

One of the most persistent errant theories in astronomy's recent history involves the luminiferous aether. "Aether" is a material that supposedly fills the universe. In Greek mythology, it was the essence the gods breathed, like air. "Luminiferous" refers to a supposed property of aether that lets it convey light.

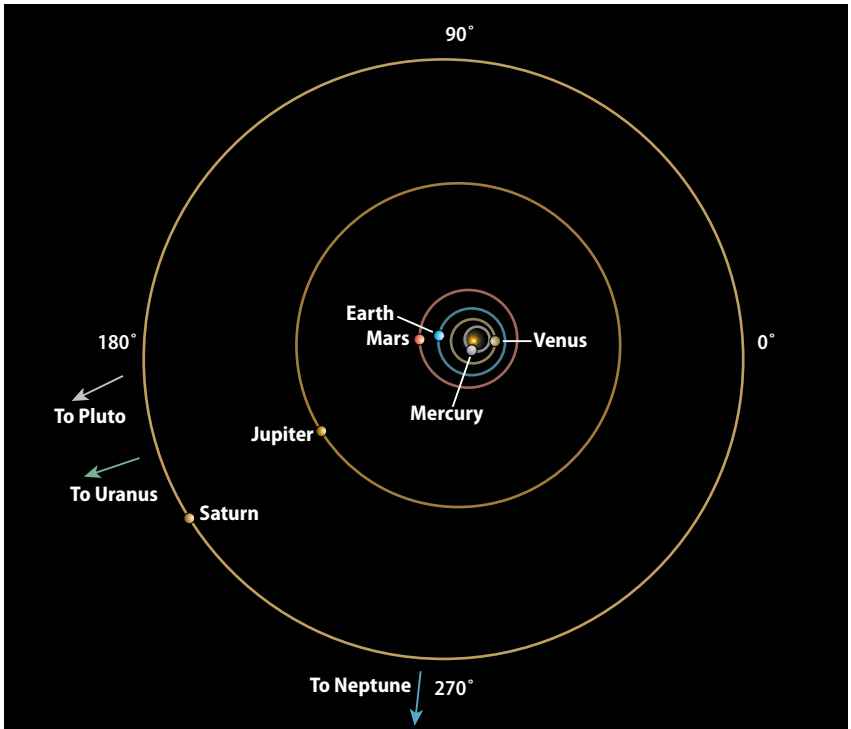
In 1690, Dutch astronomer Christiaan Huygens proposed that light waves from the Sun and other bodies traveled through an aether. In 1704, Isaac Newton also suggested an aether, but his theory dealt with the particle properties of light.

From then until the beginning of the 20th century, few scientists doubted the aether was real, although nobody had produced a shred of proof to back up its existence. In 1905, Albert Einstein presented his special theory of relativity. In it, he explained the properties of light as it travels through space, and he didn't postulate an aether. Within a few years, the idea was dead and buried in the vacuum of space.

9 Life in the hot lane

Sir William Herschel determined the Milky Way's shape, figured out the direction our Sun travels through the galaxy, discovered infrared radiation, compiled a catalog with thousands of deep-sky objects, and discovered Uranus. Unfortunately, this scientific genius also believed life exists on all the planets and the Sun.

That's right, one of the greatest astronomers who ever lived believed that the Sun had a cool, solid surface. Herschel thought our star's heat came from an intensely hot atmosphere, but a thick cloud layer shielded the surface and the beings who lived there. That's crazy with a capital C.



On March 10, 1982, the planets lined up as shown in this diagram. John Gribbin and Stephen Plagemann, the authors of *The Jupiter Effect*, made the crazy prediction that, because all the planets were on the same side of the Sun, influences would cause an earthquake on the San Andreas Fault. *Astronomy*: Richard Talcott and Roen Kelly

10 Earth died screaming?

Not every crazy idea goes back a century or more. In 1974, John Gribbin and Stephen Plagemann wrote *The Jupiter Effect*. In this best-seller, they predicted that gravitational forces from an alignment of the planets would cause dire consequences on Earth. The prediction scientists remember is that an earthquake on the San Andreas Fault would occur March 10, 1982.

On that date, Mercury, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto were within a 95°-wide interval on the same side of the Sun. Only Venus lay outside this swath. Astronomers have long recognized gravitational influences from celestial objects. The Sun's massive gravity keeps Earth in orbit. The gravity of the Sun and Moon influence the tides. Jupiter's gravity changes the orbits of comets that pass its way.

But scientists foresaw no effect from this planetary lineup, many of which had occurred throughout the 4.5-billion-year history of the solar system. The authors sidestepped the science by writing that the effect wouldn't directly impact Earth's surface. Rather, they said, it would affect the solar wind, which, in turn, influences terrestrial weather.

The writers concluded that atmospheric conditions would alter the speed of our planet's rotation, and somehow that would cause the devastation. In fact, the planets did exert an influence: High tide on March 10, 1982 was 0.04 millimeter above normal.

The future could be dark

Judging by recent stories that propose NASA faked the Moon landings, aliens carved a huge face on Mars, and the Mayans predicted the world would end in 2012, we have not seen the end of crazy astronomical ideas. Let's resolve to stay vigilant and not believe without question everything we hear or read.

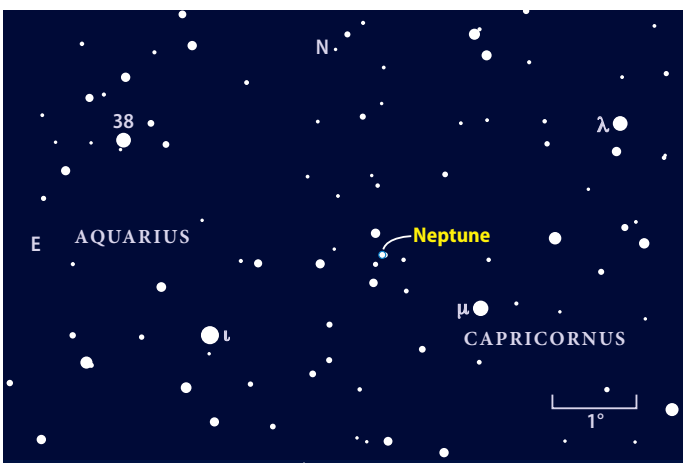
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

August 2010

Neptune returns to its origin

Neptune appears blue-gray through backyard telescopes, a far cry from its appearance to the Voyager 2 spacecraft in 1989. NASA/JPL



Neptune glows at magnitude 7.8 at opposition August 20. It then lies on the border between Capricornus and Aquarius. *Astronomy:* Roen Kelly

Four planets come into view shortly after sunset. Mercury, Venus, Mars, and Saturn gather low in the west at dusk and set within 2 hours of the Sun. Brilliant Venus stands out far more than the others.

Three more planets rise after the sky grows dark. Jupiter becomes the major attraction from late evening until dawn, but both Uranus and Neptune make worthy targets for binocular users. All seven planets provide a thrill when viewed through a telescope, although some appear more spectacular than others.

Let's begin our tour of the solar system where we normally do, in the western sky after sunset. You'll have to hurry to spot **Mercury**. It lies closer to the horizon than the other planets and appears as a mere dot shining through the twilight. The planet reaches its greatest elongation from the Sun August 6, when it lies 27° east of our star.

Greatest elongation typically marks the best time to view an inner planet, but that's not true for Mercury this month. The ecliptic — the apparent path of the Sun across the sky and one that the planets follow closely — makes a shallow angle to the western horizon after sunset at this time of year. The result: Mercury maintains a fairly steady altitude on evenings during August's first week.

36 Neptune at its best
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 A disappearing jovian moon
42 Comet search
43 Locating asteroids
43 An evening trio of planets

Visible to the naked eye
Visible with binoculars
Visible with a telescope

You can find it approximately 6° high 30 minutes after sunset. It dips below the horizon about a half-hour after that.

Mercury proves a bit easier to see when the month begins because it appears brighter. On August 1, it shines at magnitude 0.1; by greatest elongation, it has faded some 20 percent to magnitude 0.3. It continues to dim by about 10 percent every 2 days after that until it disappears from view in mid-August.

If you have a western horizon uncluttered by hills, trees, or buildings, spend a few minutes each clear night tracking Mercury's changing appearance through your telescope. On August 1, the planet spans 7" and shows a slightly gibbous

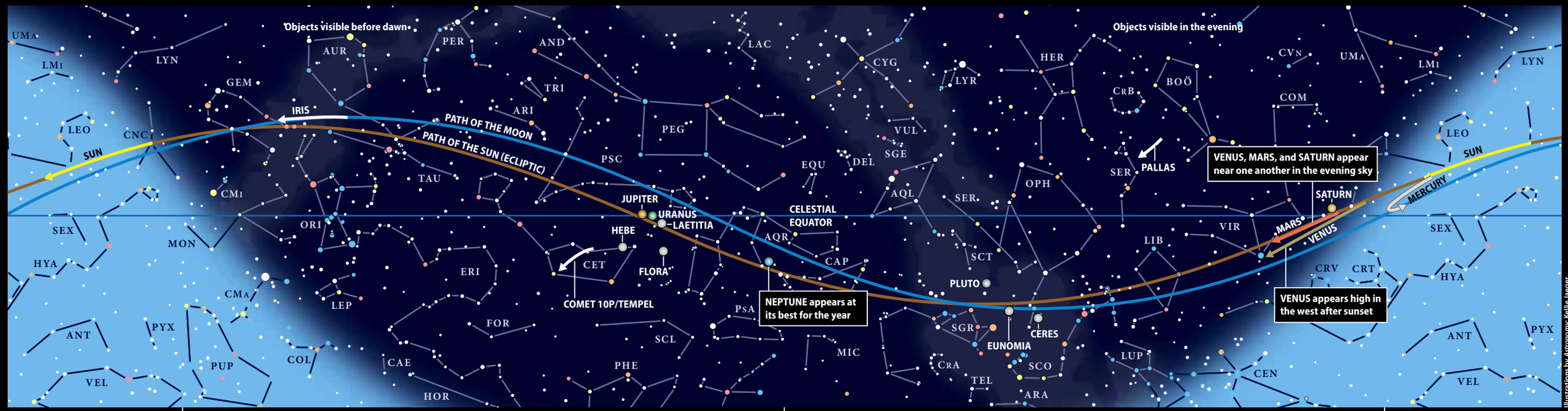
— *Continued on page 41*

Planets in August 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets

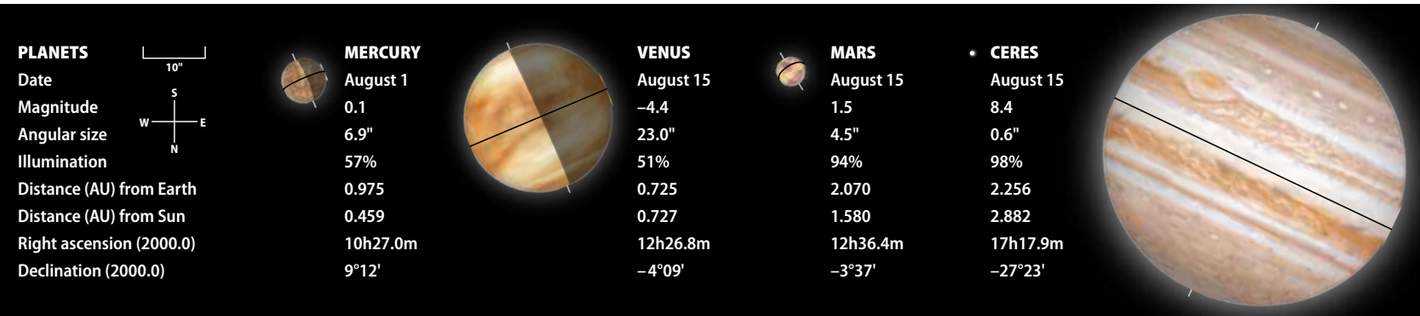


Dawn — Midnight — Early evening

MOON PHASES

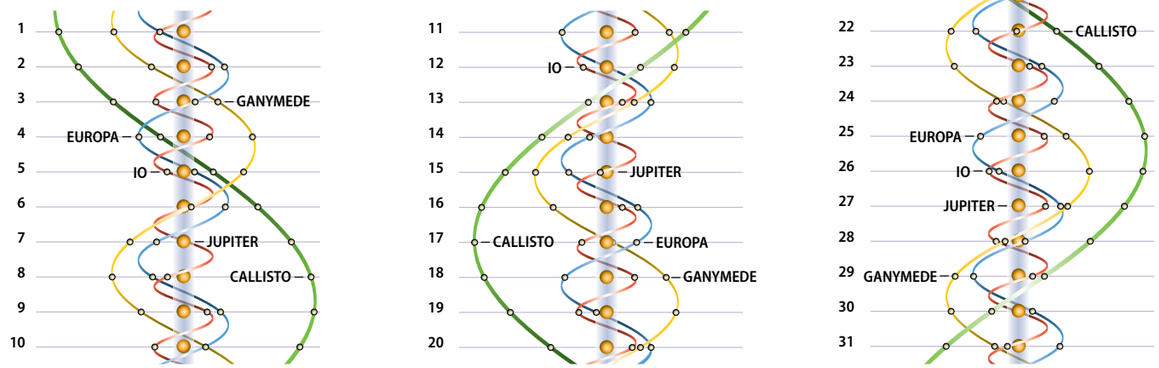
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	• CERES	JUPITER	SATURN	URANUS	NEPTUNE	• PLUTO
Date	August 1	August 15	August 15	August 15	August 15	August 15	August 15	August 15	August 15
Magnitude	0.1	–4.4	1.5	8.4	–2.8	1.1	5.8	7.8	14.0
Angular size	6.9"	23.0"	4.5"	0.6"	47.5"	16.1"	3.7"	2.4"	0.1"
Illumination	57%	51%	94%	98%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.975	0.725	2.070	2.256	4.148	10.294	19.284	29.009	31.211
Distance (AU) from Sun	0.459	0.727	1.580	2.882	4.962	9.543	20.093	30.018	31.881
Right ascension (2000.0)	10h27.0m	12h26.8m	12h36.4m	17h17.9m	0h11.3m	12h11.2m	0h00.6m	21h58.6m	18h12.0m
Declination (2000.0)	9°12'	–4°09'	–3°37'	–27°23'	–0°25'	1°11'	–0°47'	–12°52'	–18°26'



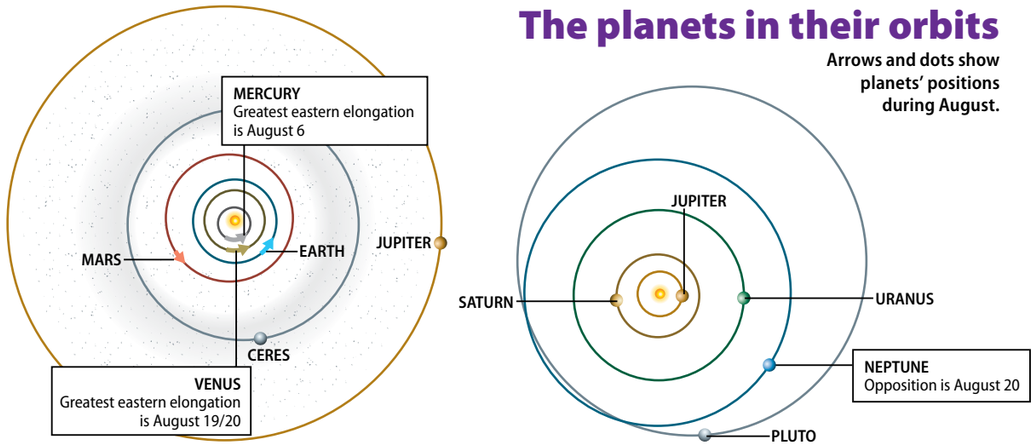
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during August.



StarDome

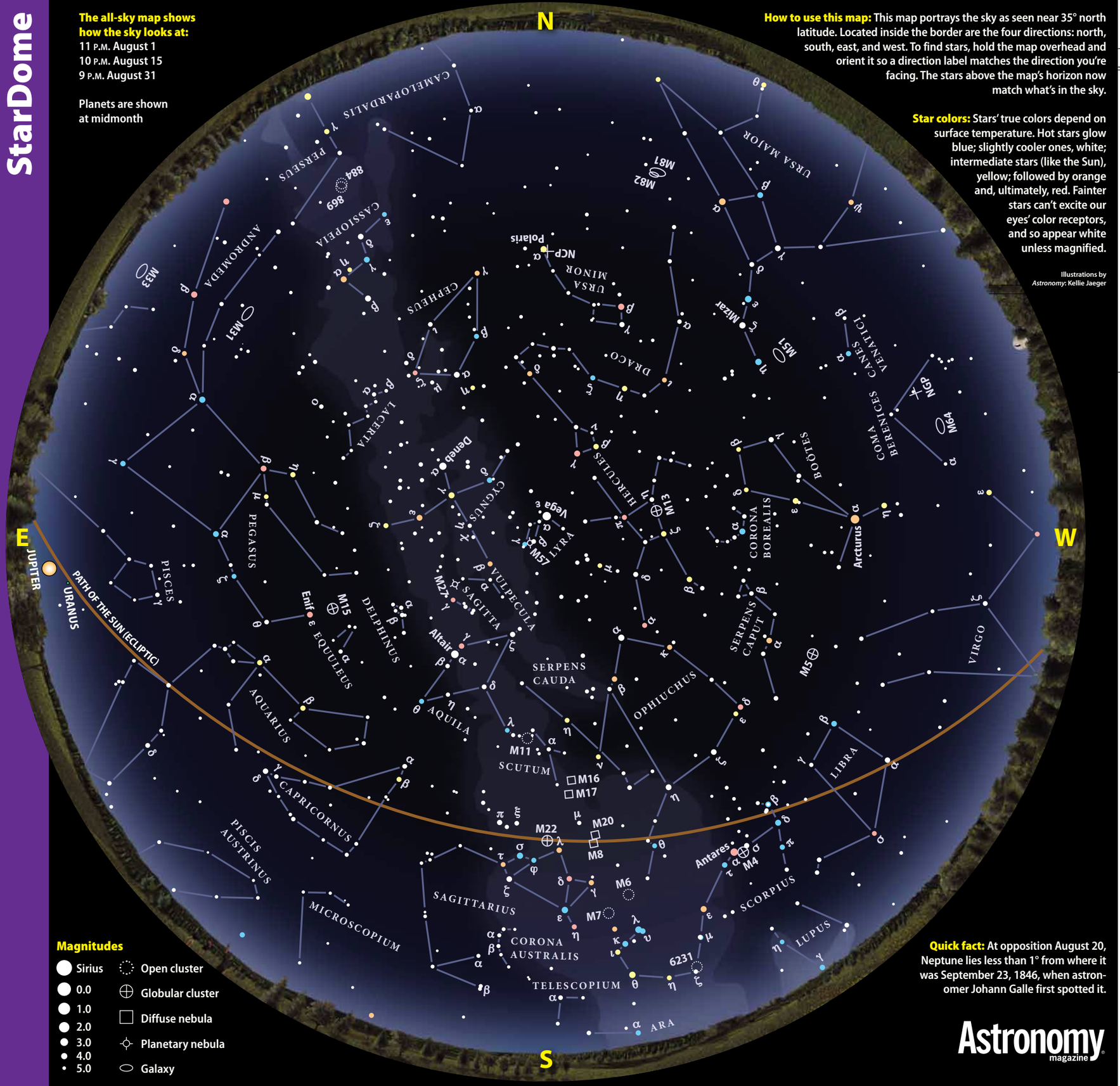
The all-sky map shows how the sky looks at:
11 P.M. August 1
10 P.M. August 15
9 P.M. August 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy:* Kellie Jaeger



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: At opposition August 20, Neptune lies less than 1° from where it was September 23, 1846, when astronomer Johann Galle first spotted it.

Astronomy magazine

August 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Calendar of events

1 Mars passes 1.9° south of Saturn, 4 P.M. EDT

3 Last Quarter Moon occurs at 12:59 A.M. EDT

6 Mercury is at greatest eastern elongation (27°), 9 P.M. EDT

8 Asteroid Ceres is stationary, 10 P.M. EDT

9 Venus passes 3° south of Saturn, 10 P.M. EDT

New Moon occurs at 11:08 P.M. EDT

10 The Moon is at perigee (222,362 miles from Earth), 1:58 P.M. EDT

11 The Moon passes 2° south of Mercury, 10 P.M. EDT

12 Perseid meteor shower peaks

Special observing date

12 With the Moon out of the sky, observers can expect to see up to 100 Perseid meteors per hour the night of August 12/13.

13 The Moon passes 8° south of Saturn, 3 A.M. EDT

The Moon passes 5° south of Venus, 8 A.M. EDT

The Moon passes 6° south of Mars, 1 P.M. EDT

16 First Quarter Moon occurs at 2:14 P.M. EDT

19 Mercury is stationary, midnight EDT

Venus is at greatest eastern elongation (46°), midnight EDT

20 Neptune is at opposition, 6 A.M. EDT

23 Venus passes 2° south of Mars, 5 P.M. EDT

24 The Moon passes 5° north of Neptune, 8 A.M. EDT

Full Moon occurs at 1:05 P.M. EDT

25 The Moon is at apogee (252,518 miles from Earth), 1:51 A.M. EDT

27 The Moon passes 6° north of Uranus, 3 A.M. EDT

The Moon passes 7° north of Jupiter, 8 A.M. EDT

See tonight's sky in Astronomy.com's STARDOME

— *Continued from page 36*

phase. Mercury appears a bit bigger by August 5, when it sports a half-lit disk. And on August 10, the innermost planet measures 8" across and appears 42 percent lit.

Although you might have to search a bit to spot Mercury's glow, **Venus** poses no such problem. The brightest planet dominates the evening sky despite its low altitude. On August 1, it blazes at magnitude –4.3 and lies about 15° above the western horizon 30 minutes after sunset.

Venus reaches greatest elongation from the Sun the evening of August 19, by which time it has brightened to magnitude –4.5. And if you think Venus dazzles then, wait until August ends and it shines at magnitude –4.6. On the 31st, the planet lies barely 10° high half an hour after the Sun goes down. It then stands 1° below the 1st-magnitude star Spica. Although Spica is the brightest star in the constellation Virgo the Maiden, it shines less than 1 percent as bright as Venus.

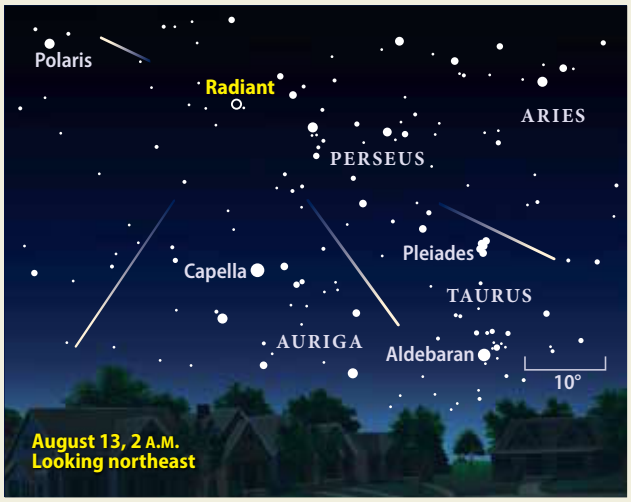
Not only does Venus win the early evening battle for brightest planet, but it also makes the most interesting target for those with telescopes. On August 1, the planet appears 20" across and 58 percent lit. By greatest elongation on the 19th, it has grown some 20 percent (to 24" across) and displays a half-lit disk. As August closes, Venus' disk swells to a diameter of 28" and shows a fat crescent phase (42 percent lit).

Mars and **Saturn** join Venus to make an attractive trio throughout most of August. On August 1, Saturn lies just 2° to Mars' upper right, and this pair stands 7° to Venus' upper left. Mars shines at magnitude 1.5 and sports an orange-red glow while Saturn shines at magnitude 1.1 and has a yellow hue.

The orbital motions of the planets cause their relative positions to change all month. On August 10, the three form a near isosceles triangle, with Venus at the bottom, Mars to

Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



Astronomy: Roen Kelly

Perseid meteors will rain down the night of August 12/13, when up to 100 meteors per hour will streak across a moonless sky.

The Perseids deserve a Hero's welcome

You may not need an excuse to take off a Friday in August, but the Perseid meteor shower provides a good one. The shower peaks under a moonless sky Thursday night, August 12/13. Observers at dark sites should see an average of at least 60 meteors per hour, and perhaps up to 100 per hour. About half as many meteors will show up a night before and after.

The meteors appear to radiate from a point in the constellation Perseus the Hero. This region lies low in the northeast during evening hours but rides high after midnight. The best views should come as dawn approaches, when the radiant climbs highest and Earth sweeps up more meteors.

Perseid meteors derive from dust grains ejected over many millennia by Comet 109P/Swift-Tuttle. These grains burn up as they hit Earth's atmosphere at 37 miles per second, creating the streaks of light we see every August.

Rising Moon

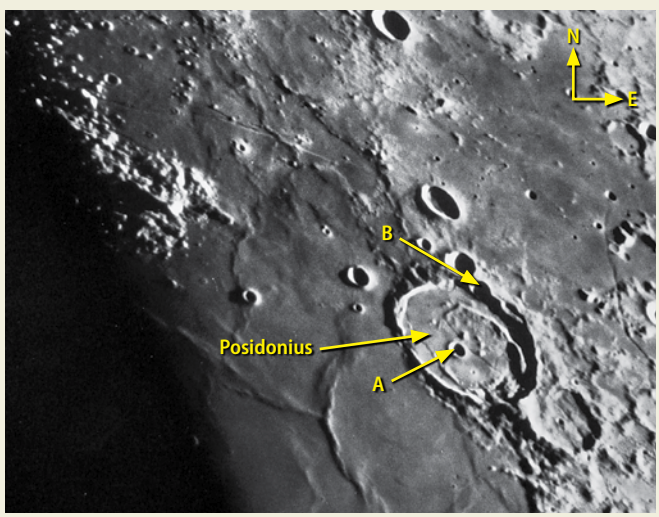
A fortnight of features from Posidonius

Packed with detail, the lava-filled crater Posidonius ranks near the top of any Moon-lover's list. Jumbled peaks, a complex system of rilles, an off-center craterlet, and bright segments of slumped walls all vie for attention within this 60-mile-wide impact crater.

Posidonius' eastern rim lights up with the rising Sun the evening of August 14. Look for the crater along the terminator, the line that separates day from night (or light from dark), about one-third of the way from the north to the south pole.

Posidonius B, a relatively recent 9-mile-wide impact scar, stands out on the crater's northeastern rim. A slightly smaller crater, Posidonius A, emerges quickly from the shadows on the main crater's floor. The view changes every hour as the Sun climbs higher over the lunar landscape and exposes new terrain. Although many craters nearly vanish at Full Moon, Posidonius boasts a bright rim with plenty of details in its interior.

This spectacular crater takes its name from the Greek astronomer and philosopher Posidonius, who lived from 135 to 51 B.C. Don't confuse this Greek with Poseidon, the Greek god of the sea.



Hills, rilles, and craterlets pack the interior of Posidonius, a 60-mile-wide crater in the Moon's northeastern quadrant. *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Jupiter (southeast)	Jupiter (southwest)
Venus (west)	Uranus (southeast)	Uranus (southwest)
Mars (west)	Neptune (southwest)	
Saturn (west)		

its upper left, and Saturn to Venus' upper right. All three lie within a 7°-diameter circle.

A slender crescent Moon passes several degrees below the trio August 12, coincidentally the peak night for an outstanding display of Perseid meteors. And on the 23rd, Venus passes 2° south of Mars. The two appear twice as far apart on the 31st, when stark-white Venus lies just below blue-white Spica; ruddy Mars appears to their right. Binoculars will offer the best view of their contrasting colors.

Although Saturn normally looks beautiful through a telescope, its low altitude this month dampens the view. The ringed planet's image shimmers as Earth's unstable atmosphere roils in the heat of a summer evening. Saturn appears 16" across in mid-August and the rings span 37". Mars fares even worse, with a disk only 5" in diameter that shows no detail.

Once these early evening planets set and the sky darkens completely, turn your attention farther east. Many people think distant **Pluto** lies beyond the reach of backyard telescopes. But you can glimpse this planet (or dwarf planet, depending on your point of view) through a quality 8-inch or larger scope under a dark sky. Pluto glows at 14th magnitude, making it the only member of the distant Kuiper Belt visible through modest instruments.

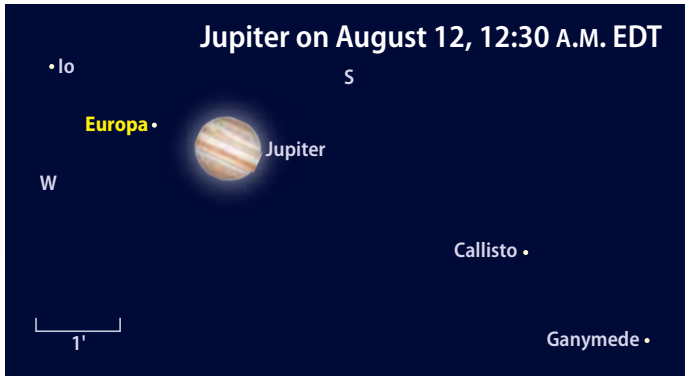
The key to spotting Pluto is knowing exactly where to look. It currently lurks in the Milky Way star fields of northern Sagittarius, some 2.7° north of 4th-magnitude Mu (μ) Sagittarii.

By late evening, **Neptune** stands about 20° high in the southeast. The outer planet reaches its 2010 peak August 20, when it lies opposite the Sun in our sky. It then rises at sunset and appears highest in the south around 1 A.M. local daylight time. It also glows brightest at opposition, reaching magnitude 7.8.

Neptune currently lies less than 1° from the spot where it resided September 23, 1846, the night German astronomer Johann Galle first glimpsed it. The planet's proximity to its discovery position shouldn't be surprising because Neptune takes 164.8 years to complete one orbit of the Sun.

The planet lies on the eastern border of Capricornus, where the Sea Goat meets Aquarius the Water-bearer. You can find Neptune with binoculars on an imaginary line connecting Mu Capricorni and 38 Aquarii. These two 5th-magnitude stars form a triangle with 4th-magnitude Iota (ι) Aquarii to their south. In early August, Neptune lies 2° from Mu Cap; the gap closes to 1° by month's end. On a night with steady seeing, point your telescope at Neptune and crank up the power. You'll see a blue-gray disk that measures 2.4" across.

Jupiter and Uranus rise together, shortly after 10 P.M. local daylight time in early August and some 2 hours earlier by month's end. **Jupiter** is glorious, shining brilliantly at magnitude –2.8 against the faint backdrop of Pisces the Fish. Only the Moon and Venus glow brighter.



Watch Europa disappear into Jupiter's shadow the night of August 11/12. This view shows the moon shortly before the shadow consumes it.

Comet search

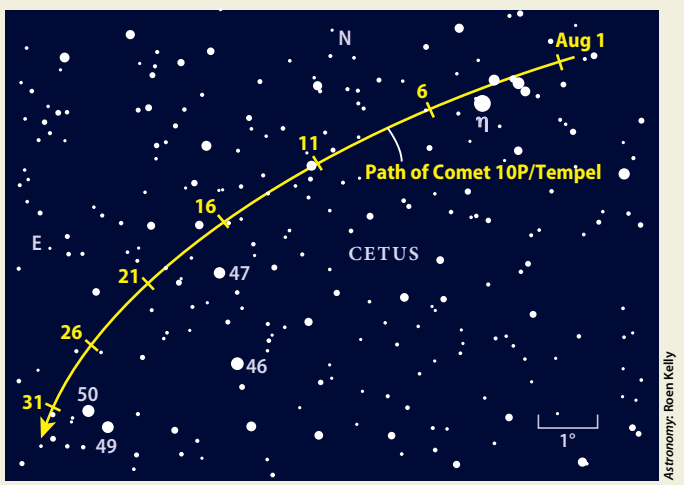
Tempel puts on a whale of a show

With a well-defined head and a short tail, Comet 10P/Tempel should give observers a late-night treat in mid-August. Away from city lights, any telescope will deliver fine views of this 8th-magnitude fuzzball. An 8-inch or larger scope will let you track the comet's condensed core from the suburbs.

Wait until 1 A.M. local daylight time for the comet's host constellation, Cetus the Whale, to climb reasonably high in the southeast. You can find 10P/Tempel between Eta (η) and Tau (τ) Ceti, a pair of 3rd-magnitude stars in southwestern Cetus.

Although astronomers predict the comet will peak at 8th magnitude, it occasionally experiences an outburst. If one happens this year, expect 10P/Tempel to brighten by a couple of magnitudes.

The comet takes 5.4 years to orbit the Sun. During this period, it loops from just inside Mars' orbital path out nearly to Jupiter's and back again. It reached its closest point to the Sun, called perihelion, July 4. We won't see another favorable return of this relic from the solar system's birth until 2026.



Comet 10P/Tempel should glow around 8th magnitude as it moves southeastward away from 3rd-magnitude Eta (η) Ceti.

Locating **asteroids**

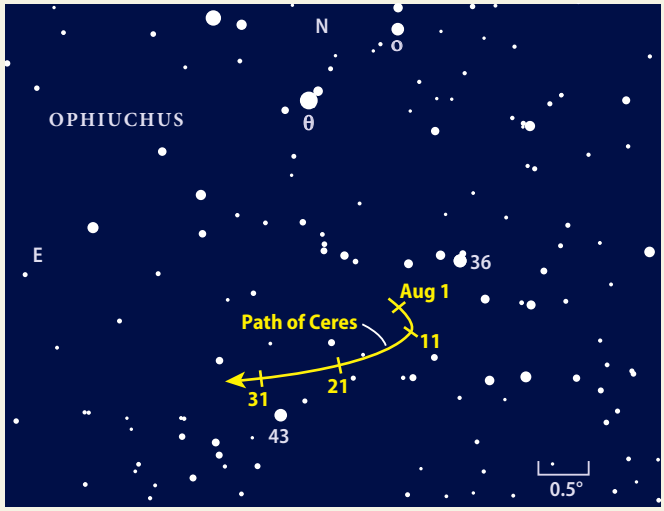
Ceres crosses a starless void

For those who enjoy viewing asteroids, the Milky Way is usually an unforgiving adversary. Pinpointing a faint point of light against this star-rich background proves to be a tougher battle than many observers care to wage. But this month provides asteroid-hunters with a rare chance for victory.

Asteroid 1 Ceres spends much of August crossing a blank portion of the Milky Way in southern Ophiuchus. Some deep-sky observers refer to this dark cloud of dust and cold gas as the stem of the Pipe Nebula while others say it's the hind leg of the Prancing Horse. A handful of stars on the cloud's near side provide enough signposts to find our solar system's largest asteroid.

Even from a city backyard, you shouldn't have trouble spying Ceres through a small telescope. Ophiuchus lies due south in mid-evening. Use the circular "StarDome" map at the center of this magazine to find Theta (θ) Ophiuchi at the constellation's southern end. Ceres stays within 3° of this 3rd-magnitude star all month.

Ceres fades from magnitude 8.1 to 8.6 in August. It appears relatively bright because it's pretty big, spanning nearly 600 miles.



Asteroid Ceres lurks in southern Ophiuchus, where it appears silhouetted in front of a dark cloud of dust and cold gas. *Astronomy*: Roen Kelly

Jupiter appears stunning through any size telescope. The planet's disk spans 48" in mid-August, just 2" shy of its late-September peak. For the best views, wait until Jupiter climbs reasonably high. In early August, this means after midnight. As the month winds down, the planet looks great by late evening.

Jupiter's thick atmosphere displays plenty of details. A telescope typically shows two dark, parallel belts that sandwich a brighter zone coinciding with the planet's equator. With a larger scope, you can expect to see a series of alternating dark belts and lighter zones. Dark regions indicate relatively warm, low-level cloud features while lighter areas are cooler and higher. Jupiter's appearance in the eyepiece changes rapidly because the planet spins on its axis in less than 10 hours.

Jupiter's four large moons offer another small-scope treat for viewers. Io, Europa, Ganymede, and Callisto orbit the planet in periods ranging from 1.8 to 16.7 days. Because their orbital paths lie nearly edge-on from our viewpoint, the moons pass in front of and behind the planet's disk once each orbit. More than 60 such transits and occultations take place in August, and an observer anywhere on Earth can see a good number of them.

Throughout August, when either Io or Europa passes behind Jupiter, it first dips into the planet's shadow and later reappears at the bright limb. Europa provides a couple of well-timed events for North America. On the night of August 11/12, the moon disappears into the shadow at 12:37 A.M. EDT and reappears at 5:17 A.M. And on August 18/19, Jupiter eclipses Europa at 3:13 A.M. EDT (the moon reappears after sunrise).

Shadow transits occur when a moon passes between Jupiter and the Sun and we see the moon's dark shadow cross the planet's face. Because Io moves the fastest, it provides the most dramatic show.

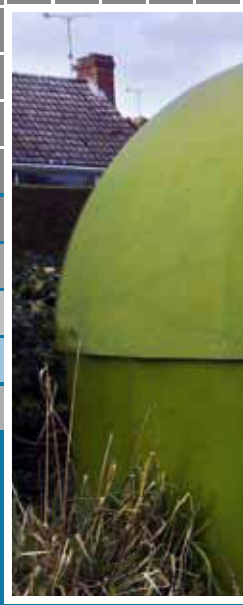
A good example occurs August 14/15 starting at 12:40 A.M. EDT. Io's shadow takes 2 hours and 14 minutes to transit the planet's disk. Io itself transits Jupiter beginning 54 minutes after the shadow transit starts, although the dark shadow proves much easier to spot against the jovian cloud tops.

Brilliant Venus stood above Saturn and Mercury in the predawn sky October 8, 2009. This month, Saturn and Mars join Venus to make a stunning evening trio. Steve Irvine

Uranus glows at magnitude 5.8, bright enough to glimpse with naked eyes under a dark sky but much easier to see through binoculars. On August 1, it stands 3° west of Jupiter; by the 31st, this gap shrinks to 1.8°.

In mid-August, a star that glows slightly fainter than Uranus lies midway between the two planets. Through a telescope, Uranus shows a 3.7"-diameter disk and a distinct blue-green color.

HOW AMATEUR ASTRONOMERS ARE REALLY DOING SCIENCE



Professional astronomers don't always catch everything in the sky. Astronomy enthusiasts are discovering near-Earth objects, measuring variable stars, and finding supernovae like never before. **by Brian Skiff**

▼ **Patrick Wils** received the 2009 American Association of Variable Star Observers (AAVSO) Director's award. Roughly each year, the AAVSO director chooses an outstanding observer to receive the award. Patrick Wils

▲ **Peter Birtwhistle** has been observing from West Birkshire, England, for 8 years. During that time, he's observed close to 5,000 minor planets. Peter Birtwhistle, Great Shefford Observatory

▲ **Barbara Harris,** shown here in her observatory, was the first to observe the rebrightening of U Scorpii January 28, 2010. Barbara G. Harris

▶ **Shawn Dvorak** was the second to see U Scorpii's eruption. He observed the star's brightening with his 10-inch Schmidt-Cassegrain in his backyard observatory. Debra Dvorak

The number of eyes (and cameras) on the sky has increased rapidly in the past decade. Nowadays, not much that is reasonably bright escapes notice because amateur astronomers are out in droves imaging the sky. They measure the brightnesses of many different types of objects, including asteroids, variable stars, and supernovae. They track asteroids' orbits. Hobbyists also look at objects' spectra — a range of wavelengths specific to the object that provides data such as composition and distance.

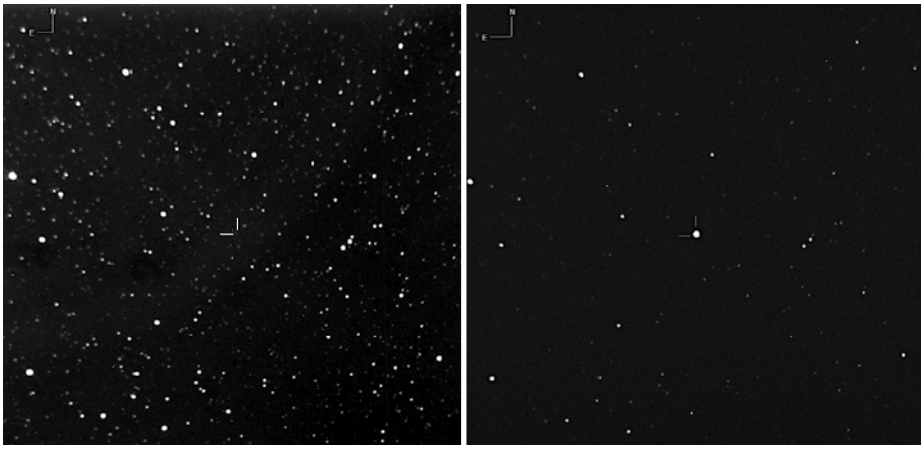
Some amateur astronomers are combining this information with data from professionals available at various online catalogs to give us a more complete view of our night sky. These astronomy enthusiasts are contributing scientific research in areas that professional studies don't — and can't — always explore.

Brian Skiff, *an astronomer at Lowell Observatory in Flagstaff, Arizona, has been discovering comets and asteroids for nearly three decades.*

Dawn patrol

Rising somewhat reluctantly before dawn on Thursday, January 28, 2010, retired doctor Barbara Harris opened up her 16-inch telescope and aimed it low in the southeastern sky just above the head of Scorpius. The target was the recurrent nova U Scorpii.

For many months prior, astronomer Brad Schaefer of Louisiana State University had claimed that the cataclysmic binary star would erupt "any day now." He originally predicted March 2009, but with



When U Scorpii erupted in the early morning hours of January 28, Barbara Harris was at her telescope to image the event. The left image shows the field 24 hours prior to eruption; the right image shows the brightened star. Barbara G. Harris

an uncertainty of a year in both directions. Schaefer encouraged a worldwide effort to monitor the star. This extended into the period when it was behind the Sun in November 2009. Would observers miss the eruption?

As soon as the field of view became accessible in early December, it was Harris who got the first ground-based images that recorded stars faint enough to show U Scorpii was still in quiescence. "Any day now" still lay ahead. So Harris kept up the vigil every morning for another 6 weeks.

Then on January 28, she took her usual CCD image and found a greatly brightened star right in the center. She verified the location and took additional short exposures so the star was not saturated and thus she could measure the brightness precisely. Then she notified the American Association of Variable Star Observers (AAVSO) and called Schaefer — who let out a "whoop!" and went outside with a small telescope to have a look with his own eyes.

Within the hour, Shawn Dvorak, a hobbyist in central Florida, got up to put his robotic 10-inch Schmidt-Cassegrain telescope away after a night of observing. It had been collecting CCD data automatically on a programmed list of variable stars. Before packing his scope up, however, Dvorak decided to aim it at U Scorpii as the sky began to brighten. He as well saw the too-bright star in the right place. His observation confirmed the event.

Harris' and Dvorak's reports allowed Schaefer to set in motion active observing both on the ground and in space. Satellites soon looked at the star at X-ray wavelengths while ground telescopes in Japan and India obtained visible and near-infrared spectra.

Gathering skills

The detection of U Scorpii by Harris and Dvorak did not come by lucky chance. Instead, it was their persistence and competence. They each spent years assembling their equipment, originally starting small and working up. Each developed the necessary skills in observing and reducing data. Then they had to be out on scores of nights, standing watch even while nothing happened. U Scorpii briefly rewarded the tedious work, and they both know this won't be the last of their discovery reports.

Both observers are significant contributors of regular variable star observations to the AAVSO. In addition, Dvorak has published more than a dozen papers in refereed science journals in the past 5 years. His work deals mainly with eclipsing binary stars that both professional and amateur astronomers have overlooked, and whose orbital periods are uncertain, unknown, or change over the decades. He uses an ordinary 10-inch telescope and CCD camera robotically so that data accumulate while he sleeps.

But even Dvorak's modest setup is not a necessity to do science. Observers, especially those in astronomically disadvantaged climates, can now use any of several rent-a-scope facilities around the world or online. Sometimes the rent is free, although often with the proviso that the user provides a reasonable science justification for a particular project.

Although the bulk of rent-a-scope use is to take "pretty pictures," more amateur astronomers are taking advantage of these telescopes to get scientific data. A common use is to make follow-up observations of transient events such as bright-

The spectrum tells nearly all

Although much of popular astronomy focuses on colorful images, nearly everything we know about celestial objects comes instead from spectra — light signatures that show objects' characteristics. The digital spectrum taken with a modern detector comes out of the instrument as a string of numbers, much as a CCD image does. But instead of being assembled as a pretty picture after some computer processing, the spectrum appears as a jagged or squiggly line. From it, we can infer much of what an object is broadcasting about itself: distances to objects, the existence of black holes in the centers of galaxies, the ages of star clusters — nearly everything that's news comes from spectra.

During the past decade, amateurs also have entered this arena in a substantial way. One exemplar is Robin Leadbeater of England. He has made a special effort to observe the mysterious eclipsing binary Epsilon (ε) Aurigae using a compact spectrograph. The dispersion of the instrument (how much the spectral colors are spread out) is high enough to follow the subtle changes in the spectrum of the supergiant and mysterious companion through the current eclipse event. — *B. S.*

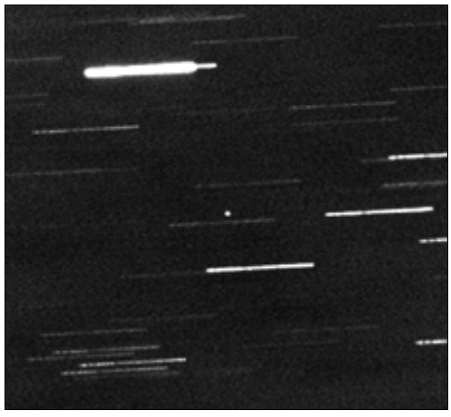
ening stars in our galaxy (called "galactic novae") or to get a lightcurve for a near-Earth asteroid (NEA).

Asteroid trails, comet tails

In the area of NEAs, even the major sky surveys do not scoop up everything in their nets. In 2009, there were 783 NEAs reported, of which 35 were by amateur astronomers. Considering how faint and large an area professional surveys can cover, even these three dozen are impressive. This research isn't just a nice addition to the work of professionals — it's indispensable.

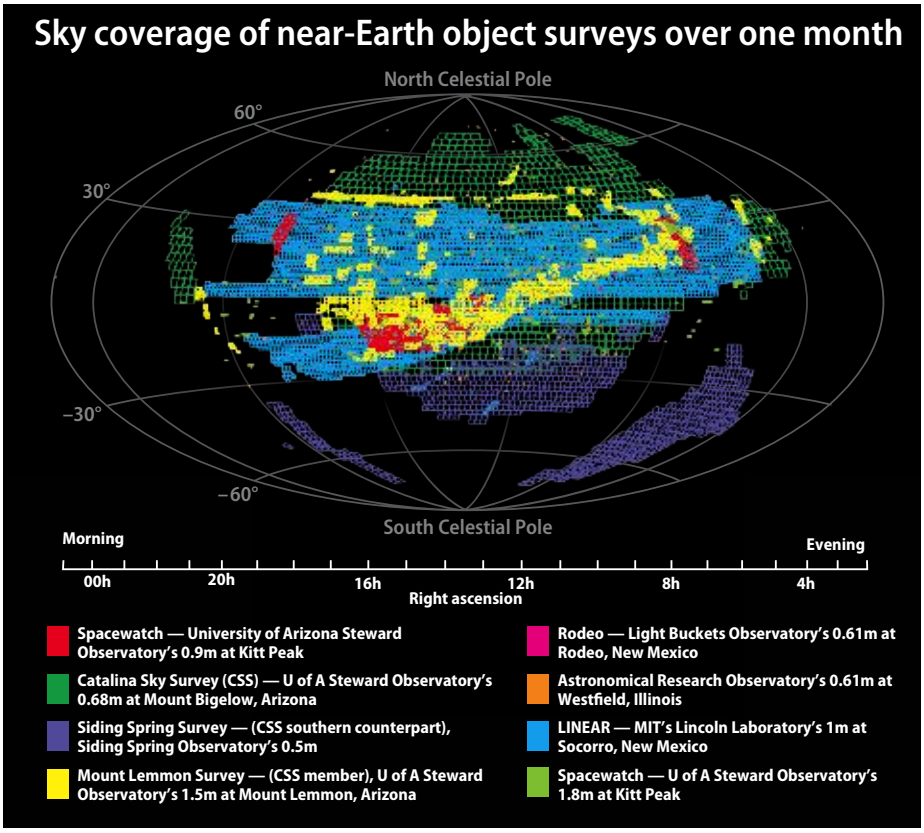
One of the most proficient observers performing the difficult follow-up work on fast-moving NEAs is Peter Birtwhistle. In 2002, he began observing from West Berkshire, England, and has gained a reputation for being able to track objects fainter than magnitude 20 with a 16-inch telescope.

Despite England's deserved reputation for cloudy weather, Birtwhistle has determined well over 10,000 precise positions of NEAs for the Minor Planet Center. In addition, he is among the first to confirm newly discovered comets that both professionals and amateurs find. And his data were among several contributed to orbit calculations in the final hours prior to the impact of meteoroid 2008 TC_3 in Sudan in October 2008.



Peter Birtwhistle, Great Shefford Observatory

Before meteoroid 2008 TC_3 fell in Sudan October 2008, many amateur astronomers tracked its orbit. Peter Birtwhistle compiled this data of the meteoroid. In this image, the object is centered and star trails fill the field of view.



Multiple near-Earth object (NEO) surveys cover large swaths of sky each month. This sky map shows how much of the sky professional surveys and amateur surveys (Rodeo and the Astronomical Research Observatory) covered between the March 29 and April 28, 2010, Full Moons. Minor Planet Center

Often when observers take follow-up NEA images, they find other asteroids in the same fields. Using this method, Birtwhistle discovered two dozen asteroids during 2009, the brightest of which glowed faintly at magnitude 18.4.

And that is just the observing side of what amateur astronomers can do. Other hobbyists perform orbit calculations; still more use the results from new orbits to trace back objects on archive images to find and measure them at earlier apparitions. Recovering and linking such second apparitions ensures that observers won't lose track of the asteroids again.

Once comfortable with astrometry (measuring objects' positions in space), observers often start to think about using their CCD images to obtain lightcurves of the asteroids they are spotting. Most asteroids are not spherical, but are instead potato-shaped. As they rotate, the surface reflects greater and lesser amounts of light, which causes them to change brightness. This allows observers to find the rotation period, set limits on the size and bulk density of the rock, and resolve other physical properties.

This activity also has a professional-amateur connection through the journal *Minor Planet Bulletin*, edited by asteroid researcher Rick Binzel of the Massachusetts Institute of Technology and amateur astronomer Brian Warner of Palmer Divide Observatory, Colorado. The quarterly publication presents more than 100 asteroid lightcurves in each issue — hobbyists compiled nearly all of them.

Warner has worked assiduously to produce software tailored for asteroid lightcurves. He also coordinates campaigns to observe binary asteroids, whose long periods require data taken at widely spaced longitude intervals around the world.

NASA/ESA/H. Hammel (Space Science Institute, Boulder, Colo.), and the Jupiter Impact Team

In July 2009, amateur astronomer Anthony Wesley saw a dark splotch on Jupiter. He quickly realized it was likely an impact scar, so he notified the professionals. Astronomers used the upgraded Hubble Space Telescope to follow up on the impact.

Spotting changes

There are few limits, it seems, to systematic amateur observing. Astronomy enthusiasts spot almost all ordinary galactic novae. Most of this occurs nowadays with CCDs or digital cameras attached to telephoto lenses. To some extent, actually finding the novae amongst the crowd of stars in the images can be automated, but it still requires human verification and follow-up. There are also a few hobbyists using film, and a dwindling number of visual nova hunters.

In July 2009, a small object — likely icy — impacted Jupiter. Australian astro-imager Anthony Wesley was the first to spot Jupiter's new scar. Wesley noticed that something was amiss — this particular little dark blob was not just another disturbance in the turbulent cloud bands. He recognized it as remarkable because he had taken many similar images and examined them in detail, and thus became familiar with the gradual but continual changes in the jovian atmosphere.

The current eclipse of the naked-eye star Epsilon (ε) Aurigae is another case where amateur astronomers provide research-quality data, and where patience is a virtue. Because the star is so bright, few professionals have the appropriate equipment to measure its brightness — an area called "photometry." But Arizona observer Jeff Hopkins has done precise single-channel photometry on the star from his backyard for 30 years, an indispensable data-string. He is one of the principals coordinating amateur observations of the star, including spectroscopy.

The hunt for supernovae is another active and competitive field. Dozens of observers image thousands of galaxies to check for changes. Each year, despite professional surveys, amateur astronomers find scores of supernovae.

It is particularly important to obtain spectra of supernovae — mere magnitude estimates are not that valuable. Thus several professional observatories perform follow-ups of amateur discoveries, a reverse of the situation for NEAs.

Among the best supernova hunters is Berto Monard in South Africa. Although his telescope isn't especially large (12 inches), he has the advantage of having the southern sky pretty much to himself for supernovae. In 2009, he found more than a dozen. In between supernova hunting, he does photometry of dwarf novae and monitors the bizarre and poorly understood symbiotic binary stars.

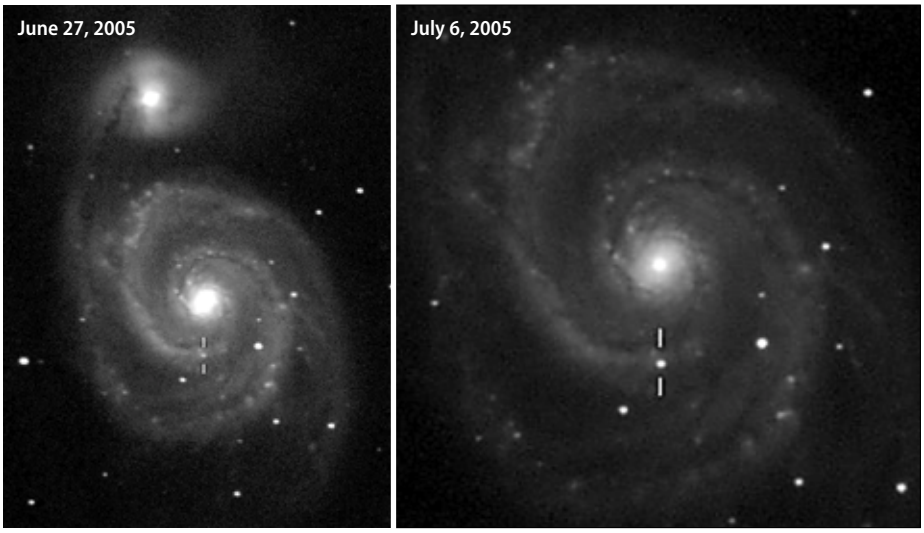
Careful visual observers also contribute. By making unusually accurate naked-eye magnitude estimates, Sebastian Otero of Argentina found that 2nd-magnitude Delta (δ) Velorum is an eclipsing binary system. The well-known eclipser Algol (Beta [β] Persei) drops by 1.2 magnitudes during its eclipse every 2.9 days and is easy to follow visually. Delta Velorum, however, changes by only 0.3 magnitude, and the eclipses happen once every 6 weeks. Many visual observers have a hard time even noticing a 0.3-magnitude difference between two stars, much less seeing a bright star change by that small amount. This is just one of Otero's interesting discoveries.

Data-mining and combining

Amateur astronomers can also study data cataloged by professional surveys. Vast resources are publicly available, such as images, spectra, and photometric data from the Sloan Digital Sky Survey. This catalog includes about 350 million stars and galaxies with brightness measurements at five different wavelengths across the visible spectrum, as well as more than a million spectra.

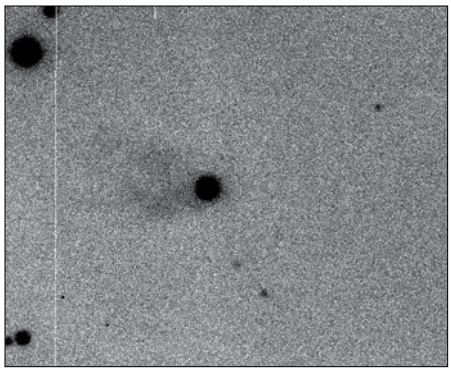
One way to find images of objects is through Goddard Space Flight Center's *SkyView* utility, which houses images throughout the electromagnetic spectrum. This service includes traditional digitized sky survey plates, infrared source images, and more.

For those with an interest in variable stars, various surveys take data, and

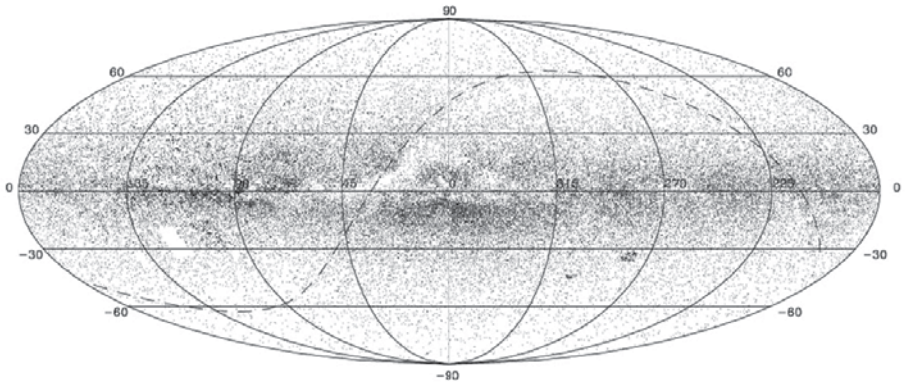


Peter Birtwhistle, Great Shefford Observatory

Amateur astronomers can fill in details of other observations. Peter Birtwhistle imaged SN 2005cs (shown in the crosshairs) shortly after it exploded but before it was discovered. He then photographed it again after hearing the announcement of a new supernova. Notice how it brightened.



Amateur astronomer Patrick Wils noticed a bright star near a nebula in survey data. Professional astronomers followed up on the object, and the collaboration determined that this object was a young star with its newly formed nebula. Wils, P./Greaves, J./the CRTS collaboration



The All Sky Automated Survey-3 has detected about 50,000 variable stars from two observatories — one in Chile and the other in Hawaii. This plot shows the stars detected over ASAS-3's 10 years. ASAS

observers put it online. One such project is the All Sky Automated Survey-3 (ASAS-3) system operated by Grzegorz Pojmański in Poland. The telescopes — telephoto cameras really — take data every clear night at Las Campanas Observatory in Chile, where there are more clear nights than just about anywhere in the world. The data-reduction pipeline produces visual magnitudes for stars between about magnitude 7 and 14 for the two-thirds of the sky accessible from northern Chile: Roughly every 3 days, the observatory images every part of the sky south of about 28° north declination. This system has discovered several novae and comets. Recently, ASAS-3 set up two more telescopes atop Haleakala, Hawaii.

Data from published catalogs is also accessible to the hobbyist. A good place to start is with the VizieR catalog query service, which the Centre de donnees astronomiques de Strasbourg (Astronomical Data Center at Strasbourg Observatory) in France maintains. (All the pages are in English.) Some 8,000 entries are available, including well-known catalogs and data tables from hard-to-get journal articles.

"Data-mining" from such resources is a good way to learn how to use what's available. But those who want to make interesting discoveries of transient events (and even new types of objects) link existing catalog data and archive images with new data. An example is the Catalina Real-Time Transient Survey. In November 2009, Belgian amateur astronomer Patrick Wils noticed a new bright star and nebula in the data that he linked with existing far-infrared survey measurements. Through personal connections at professional observatories, he was able to have a spectrum taken. This showed that the object was likely the eruption of a young star from its natal cocoon, like McNeil's Nebula discovered in 2004. (For more about McNeil's Nebula, see Adam Frank's "How an amateur changed stellar astrophysics," in the November 2009 issue.)

Being able to notice changes like this comes from an intimate familiarity with the sky — both a lot of eyepiece time and working with images. For Wils, this results from doing yeomanly work in the background to identify and catalog variable stars of all types and making detailed studies of their lightcurves.

Many astronomy enthusiasts are doing real science and know the true value of the result lies in persistence and consistency. These amateur astronomers are taking their knowledge of the sky and making scientific discoveries of their own while contributing to professional work.

Getting connected to citizen science

For readers in the United States getting started with systematic observing, there are two excellent points of contact: the American Association of Variable Star Observers (AAVSO) and the Society for Astronomical Sciences (SAS).

For a long time, the AAVSO has been a coordinating organization for all types of variable star astronomy. It now has much greater visibility and professional support thanks to the efforts of director Arne Henden and his dedicated staff. It is perhaps the best group for beginners because it provides a large amount of introductory material at its website (and now in several languages). The group also has led efforts for transient events, as well as campaigns with specific professional direction involving the response of the Hubble Space Telescope, X-ray spacecraft, and so on.

The SAS is an amateur-led group of active observers. Although there is some overlap with the AAVSO, the group concentrates more on technical matters such as hardware and software, and data reduction and analysis.

Both organizations hold meetings where observers can learn about the astronomy of the targets they're observing, how to run various software, and meet other folks doing it. The science standards are high, but you will learn a lot of astronomy by getting into these citizen science activities. — *B. S.*

Want to do some backyard science? Visit www.Astronomy.com/toc for resources mentioned in this article.

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

Shooting star colors

Q: I saw a shooting star tonight; as it burnt up in the atmosphere, it became a brilliant green. I have seen only yellow and white ones before. What causes the green color? Or could I have seen space junk burn up? — Matt Pearson, Mildura, Australia

A: Something in space that also blazes through our atmosphere is called a "meteoroid." The streak of light you see — often called a falling or shooting star — is a "meteor." Very bright meteors are "fireballs." And if a fireball breaks up, it is called a "bolide." If the meteoritic material makes it to Earth's surface, then it is a "meteorite."

The colors of meteors or fireballs are due to the light emitted from the atoms that make up a meteoroid, as well as the atoms and molecules in the air. As a meteoroid enters Earth's atmosphere at high speed, the interaction between the object and the air creates heat and light energy. Imagine rapidly rubbing your hands together — they will get hot after awhile! The same idea (friction) is at work in both cases.

A green meteor is a rare sight. This November 1998 Leonid meteor gets its color from a combination of effects, including magnesium in the meteoroid's composition. Rick Schmidt

As the meteoroid heats up, its atoms emit light of varying colors that depend on the metal or compound: sodium produces an orange-yellow color; iron, yellow; magnesium, blue-green; calcium, violet; and silicates, a decidedly red color. Most meteoroids/meteorites are stony, so they contain a high percentage of silicates. Earth's atmosphere — which is mostly nitrogen and oxygen — also produces a red glow. **Seeing a green meteor indicates magnesium composition.**

An entering meteoroid's speed can also affect the meteor's color. And whether the atoms in the air or the meteoroid's metal emissions dominate will affect what we see.

Human-made space junk — such as re-entering rocket boosters and other satellite debris — do have characteristic colors depending on the predominant material in the structure. Usually such meteors are very bright. **— Mike Reynolds,** Florida State College, Jacksonville

THE DARK NIGHT

Q: The universe has billions of galaxies and billions of stars, so why is space dark? — John E. Mortensen, Easton, Pennsylvania

A: The mere fact that the night sky is dark encodes profound cosmological information. Imagine that the universe is (1) infinitely large, (2) infinitely old, and (3) uniformly filled with normal stars that shine forever with constant brightness. Such a universe is a natural extrapolation of the apparently unchanging appearance of the celestial sphere. But what would the night sky look like in this eternal universe? The few nearby stars would each be bright, and numerous distant ones fainter. But eventually, any line of sight would meet the surface of a star. In such a universe, the entire night sky would be as bright as the Sun!

That a conclusion so absurd follows from reasonable assumptions was first pointed out long ago. This deduction is named Olbers' paradox after German amateur astronomer Heinrich Olbers, who pondered the question in the 1800s.

To resolve the paradox, at least one of our assumptions must fail. While the universe appears to be infinite in size, assumptions (2) and (3) are both grossly wrong: **at 13.7 billion years, the universe is old but not infinitely so, and stars themselves have finite life spans.** A glance at the dark night sky thus elegantly demonstrates that we live in an evolving universe. **— Brian Fields,** University of Illinois, Urbana-Champaign

SUPER BLACK HOLE

Q: If all the known matter in the universe were compressed into one colossal black hole, how big would it be (both size and mass)? — Mickey Haney, Redondo Beach, California

A: This is a slightly tricky question because the universe may actually be infinite in size and mass! It's thus simpler if we restrict ourselves to the "visible universe," the part of the universe we can see since the Big Bang. This corresponds to a distance of about 46 billion light-years and **a total mass of about 10 billion trillion times our Sun's mass** (that is, 10^{22} solar masses).

A black hole of that mass would itself have a size of billions of light-years. The similarity between the size of such a black hole and the size of the visible universe is not a coincidence: The universe is on the hairy edge between expanding forever and collapsing back in on itself. — **Eliot Quataert,** University of California, Berkeley

ORBITAL MECHANICS

Q: How difficult is it to launch an artificial satellite into a circular orbit versus an elliptical one? Is the final altitude of the orbit a key factor? — **Grant Miller,** Warrensburg, Missouri

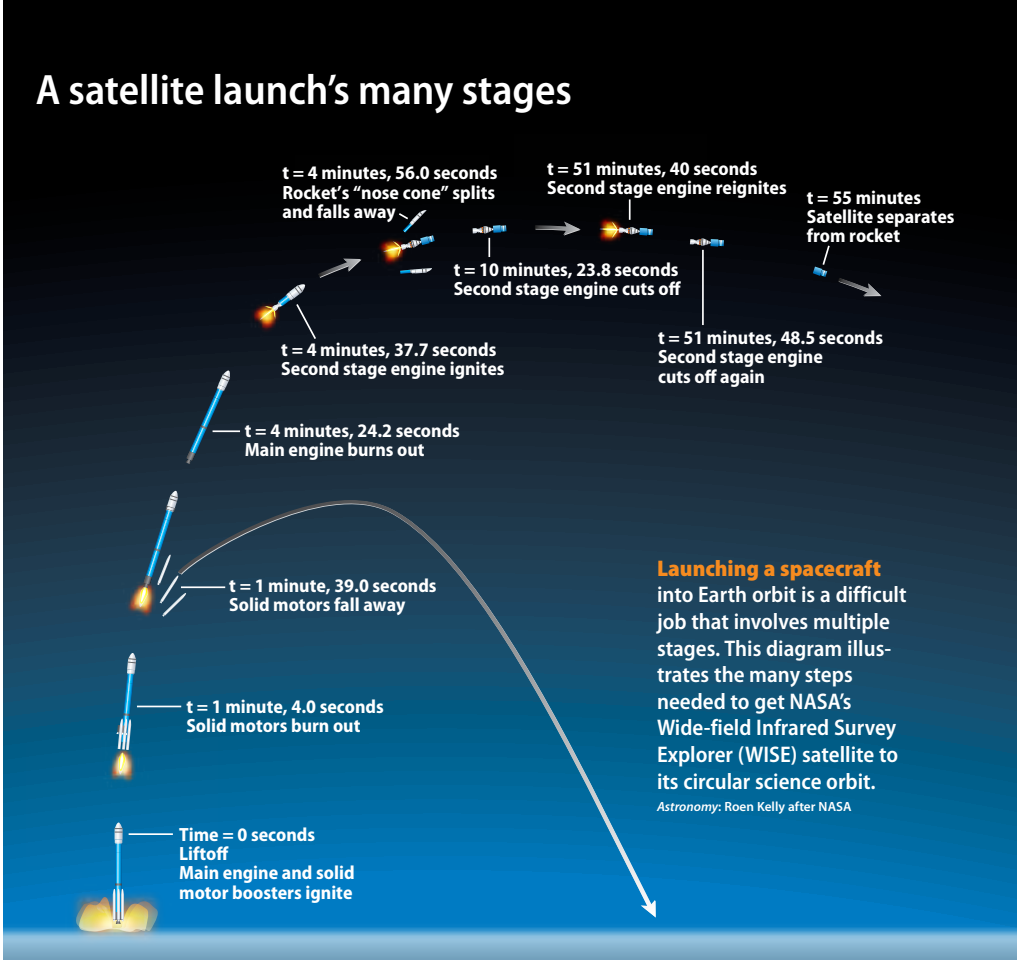
A: Astronautical engineers often say that the most difficult part of any space mission is getting into Earth orbit. It matters little if the orbit is circular or eccentric — both are difficult. The altitude is not a key factor. Success depends on three fundamental technologies: the staging of rockets, high thrust levels, and some form of automatic guidance.

To achieve high thrust, engineers often strap expendable tanks or solid rockets on a large liquid-fueled first stage. A second or third stage delivers the payload to orbit.

When the fuel burns out of the second or third stage (the number of stages depends on how much burnout velocity is needed for a given payload), the rocket is actually in level flight with Earth's surface. Effectively, small guidance rockets steer the main rocket from vertical ascent into this level flight path. With sufficient velocity at burnout, the rocket is in low-Earth circular orbit.

If the velocity is less than this circular velocity, the upper stage will re-enter the atmosphere and return to Earth's surface.

Visit www.Astronomy.com/toc to find out the difference between a cubewano, plutino, and Kuiper Belt object.



With a velocity greater than circular velocity, the craft will be in an "eccentric orbit." The burnout altitude gives the closest approach distance (or perigee). How much the burnout velocity exceeds the circular velocity determines the greatest distance (or apogee). Once in this low-altitude parking orbit, practically any space mission is possible. The only limits are the rocket's capability to get the craft into Earth orbit and the mass of the payload it carries. — **John Anderson,** Jet Propulsion Laboratory, Pasadena, California

COSMIC CONSTITUENTS

Q: Could the elusive neutrino particle be a component of dark energy? — **Richard Vaun,** Holley, New York

A: "Dark energy" is a generic name for the mysterious component of the universe that seems to be accelerating cosmic expansion. Dark energy must have negative pressure. **A particle (whether a neutrino or something else) cannot supply negative pressure, so the answer is "no."**

On the other hand, some scientists noticed that observations of dark energy exhibit properties similar to the neutrino mass. This coincidence inspired theories in which the origin of the neutrino mass and the origin of dark energy are connected. **So while not a component of dark energy, neutrinos may be somehow related to its existence.**

Associating the neutrino with the universe's dark ingredients has a long history. In the early 1930s, theories began hinting at the existence of dark matter (the mysterious mass that makes up about 23 percent of our universe) and the neutrino. Later, the neutrino topped the list of dark matter candidates simply because, since 1965, we had proven that it exists. Because the neutrino interacts only weakly, it is "dark," and we now know such particles have a small mass (but at the time we didn't know what its mass was). Unfortunately, it was also clear that neutrino dark matter couldn't contribute to a universe as we know it.
— **Francis Halzen,** University of Wisconsin-Madison

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Challenge yourself with the Palomar globular clusters

Pull out your large scope, head to a dark site, and test your skills with these 15 extreme targets.
by Phil Harrington

When researchers released the Palomar Observatory Sky Survey more than a half-century ago, it showed the universe at a level of detail never before achieved. Astronomers immediately turned to the survey's more than 900 photographic plates to examine known objects in exquisite detail and discover other sights that earlier studies had missed.

While analyzing the survey, George Abell, along with Halton Arp, Walter Baade, Edwin Hubble, Fritz Zwicky, and other prominent astronomers, cataloged 15 faint Milky Way globular clusters. Observing each is a daunting test for today's most diehard deep-sky observers. Try your luck with the six described here, and then branch out to observe the rest.

A cluster sampling

The list's leadoff member is also one of the toughest to spot. **Palomar 1** lies in northern Cepheus and never sets for most observers in the Northern Hemisphere. Not only is Palomar 1 the most northerly globular cluster known, but it is also one of the youngest, at less than 8 billion years old.

Finding Palomar 1 is tough because of its sparse surroundings, the cluster's loose stellar structure, and its magnitude 13.2 faintness. The poor central concentration lowers the overall surface brightness, which further conceals an already demanding target.

Palomar 2 in Auriga is another tricky cluster to spot because the dark nebula Barnard 221 partially conceals it. The dark nebula may not be readily evident by eye, but it has a stifling effect on the globular cluster.

Palomar 2 may be visible through telescopes with apertures as small as 8 inches under a dark sky. Given suburban skies, however, I need my 18-inch reflector to make out the globular's magnitude 13.0 smudge that appears to span less than 2'. Averted vision is a must; it, combined with a telescope of magnification greater than 150x, gives the best view. Overall, Palomar 2 looks more like a distant galaxy than a globular cluster.

Palomar 4 lies about 3½° southeast of the 4th-magnitude star Alula Australis (Xi [ξ] Ursae Majoris), the big toe on the Great Bear's hind leg. The globular's far-flung distance (coupled with its inherently weak stellar concentration) conspires to dilute the cluster's appearance to nothing more than a quiet magnitude 14.2 glow just 1.4' across. My 18-inch at 206x shows the softest whisper of the cluster, and then only fleetingly with averted vision.

A relatively young globular cluster at about 8 billion years old, Palomar 1 became incorporated into the Milky Way Galaxy after our galaxy's formation. One thought is that our galaxy cannibalized a small dwarf galaxy, and Palomar 1 is part of the leftovers. Anthony Ayiomamitis

Astronomy *contributing editor* **Phil Harrington** *is the author of the upcoming book* Cosmic Challenge *(Cambridge University Press).*

Palomar 2

Palomar 2 lies in the direction opposite the galactic center. It floats in the galaxy's halo, some 90,000 light-years from Earth. Anthony Ayiomamitis

Palomar 3

This distant globular — Palomar 3, the third-most-distant known in the Milky Way — lies about 300,000 light-years from our Sun. Anthony Ayiomamitis

Palomar 4

Palomar 4 is the second-most-distant Milky Way globular cluster known, some 350,000 light-years from the Sun. Anthony Ayiomamitis

Palomar 5

The Milky Way's gravity is tearing apart Palomar 5, forcing stars to leave the globular cluster as a stellar stream. Chris Schur

Palomar 6

Palomar 6 is one of only four globular clusters known to contain a planetary nebula — the remnant of a Sun-like star. Daniel B. Phillips

Palomar 7

Palomar 7 is one of the brighter catalog members at magnitude 10.3. It's also the largest at about 7.1' wide. Rick Beno

The rich star fields of Sagittarius are home to Palomar 8. This globular cluster is about 42,000 light-years from the Sun. Anthony Ayiomamitis

The brightest Palomar globular cluster, Palomar 9 is also known as NGC 6717. It sits just 2' away from magnitude 5.0 Nu^2 (ν^2) Sagittarii. Anthony Ayiomamitis

Palomar 10 appears as a 13th-magnitude glow. Its position in Sagitta doesn't make it any easier to see. Anthony Ayiomamitis

Palomar 11 is the second-brightest Palomar globular cluster. This object sits in a field with few bright stars. Anthony Ayiomamitis

Locate the Palomar globular clusters

Name	Constellation	R.A.	Dec.	Mag.	Size
Palomar 1	Cepheus	3h33m	79°35'	13.2	1.8
Palomar 2	Auriga	4h46m	31°23'	13.0	1.9
Palomar 3	Sextans	10h06m	00°04'	14.3	2.8
Palomar 4	Ursa Major	11h29m	28°58'	14.2	1.4
Palomar 5	Serpens	15h16m	–00°07'	11.8	6.9
Palomar 6	Ophiuchus	17h44m	–26°13'	11.6	1.2
Palomar 7	Serpens	18h11m	–07°12'	10.3	7.1
Palomar 8	Sagittarius	18h41m	–19°50'	11.0	4.7
Palomar 9	Sagittarius	18h55m	–22°42'	9.3	3.9
Palomar 10	Sagitta	19h18m	18°34'	13.2	3.5
Palomar 11	Aquila	19h45m	–08°00'	9.8	3.2
Palomar 12	Capricornus	21h47m	–21°15'	12.0	2.9
Palomar 13	Pegasus	23h07m	12°46'	13.8	1.8
Palomar 14	Hercules	16h11m	14°57'	14.7	2.1
Palomar 15	Ophiuchus	17h00m	–00°32'	14.0	4.0

R.A.=Right ascension (2000.0); Dec.=Declination (2000.0); Mag.=Visual magnitude; Size=arcminutes

In 1784, William Herschel discovered magnitude 9.3 **Palomar 9**. He included this globular in the *New General Catalogue* as NGC 6717. Abell and his colleagues were apparently unaware of this when they included it as the ninth object in the Palomar catalog.

Palomar 9 is the brightest of the bunch. Spotting it, however, can be a challenge because it lies just 2' southwest of magnitude 5.0 Nu^2 (ν^2) Sagittarii. I can just catch sight of it through my 4-inch refractor at 100x as a small puff exhausted from the star. By doubling the magnification and moving the star just out of the field of view, the globular reveals a brighter core. Resolution, however, is dif-

Shortly after astronomers discovered Palomar 12, some classified it as the Capricornus Dwarf, a small galaxy in the Local Group. Daniel B. Phillips

One of the smallest Palomar globular clusters, number 13 is roughly 2' in diameter. It lies about 84,000 light-years from the Sun. Anthony Ayiomamitis

Palomar 14 is the sixth-most-distant globular cluster known, at 240,000 light-years from the Sun. It's the faintest Palomar globular. Anthony Ayiomamitis

Can you see Palomar 15 in this image? The faint glow of this magnitude 14.2 globular cluster lies in the center of the field of view. Anthony Ayiomamitis

ficult because Palomar 9's brightest stars glow dimly at 14th magnitude.

Palomar 11 in Aquila is the second-brightest cluster discovered by Abell and colleagues on the list. Like some other Palomar globulars, the 11th object is relatively nearby at 42,000 light-years away. But it's a victim of circumstance. Between it and us are rich clouds of interstellar dust that muffle the cluster's true luster. Were it not for these nearly opaque clouds, magnitude 9.8 Palomar 11 would undoubtedly be more spectacular.

Palomar 11 lies 2.2° east-southeast of 5th-magnitude Kappa (κ) Aquilae. My 10-inch reflector reveals a circular glow adjacent to and surrounding several faint stars. A couple of the faintest points are definitely members of the cluster, although even the brightest barely breaks 15th magnitude. A magnification around 125x seems best for bringing out the cluster. Using higher magnification causes it to fade into the background.

Autumn's Pegasus is best known to fans of globular clusters as home to M15, one of the season's finest targets. But did you know that there is a second globular in Pegasus that's within the grasp of a 10-inch telescope? Although **Palomar 13** shines only at magnitude 13.8, zeroing in on it is simple thanks to its position 2½° south-southeast of magnitude 2.5 Markab (Alpha [α] Pegasi) in the Great Square.

Palomar 13 is one of the smallest and faintest globular clusters known, and you'll need to use a bit of extra effort to see it. With averted vision through my 10-inch at 212x, I can just make out a small, hazy spot. I can find no evidence of a central concentration, but instead see only a dim, featureless blur.

Try the chase

Hunting Palomar globular clusters is a fun sport for those looking for a different sort of observing project that, just more than a half-century ago, didn't even exist. Set up your large scope and give this challenge a try on the next dark, clear night.

Backyard astronomy on a budget

Amateur astronomy might seem like a daunting hobby, but you don't need much to get started.

by Glenn Chaple

All you need to watch the Perseid meteor shower (or any meteor shower) is a dark sky, your eyes, and a lawn chair. Eddie Pavlu

Have you ever gazed in awe at a star-filled sky, wishing you had the means to explore its wonders firsthand? Well, you're not alone. Many of us observers lack the wealth to purchase that high-power, high-tech, high-priced telescope we might believe is necessary for the job. We're beachcombers, gazing wistfully at the open sea, wishing we could afford a yacht.

A common misconception among newcomers to backyard astronomy is that you need a large, high-power telescope to explore the night sky. Not so! While still in college, I purchased a used 3-inch reflecting telescope for $15 that came with a 60x eyepiece.

My adventures with that little telescope included the Moon and its myriad craters and features, all of the planets, a few dozen comets, more than 100 asteroids, some 1,500 multiple star systems, and more than 200 deep-space objects (including the entire Messier Catalog). Think what a 6- or 8-inch telescope with greater light grasp and 2 or 3 times the magnifying power can do.

Would-be seafarers don't need to start out with yachts, and neither do we have to embark on our maiden cosmic voyage with large, expensive telescopes. It's time to set sail on the starry sea!

Nothing beats seeing the Milky Way arching overhead on a summer night, except perhaps glimpsing bright Jupiter (at top) in the foreground. Such a view doesn't require an expensive telescope. Instead, all you need is your eyes. Mike Salway

The naked eye

You already have the first necessary tool for backyard astronomy — your eyes! Even without optical aid, you can take in a large expanse of sky, capturing heavenly sights that a telescope (with its relatively small field of view) can't. Nothing matches the grandeur of the sky from a dark site as seen with the naked eye — especially during summer when the Milky Way arches overhead.

The naked eye provides a ringside seat to all-sky events like this month's Perseid meteor shower. You can track the Moon's nightly phase changes, follow the stately

Glenn Chaple *is an* Astronomy *columnist who often covers beginning observing topics.*

wandering of a planet against the background stars, and even record the magnitude changes of a bright variable star. You'll spot bright deep-sky objects like the Pleiades star cluster (M45), the Orion Nebula (M42), or the Andromeda Galaxy (M31). (Yes, you can see a galaxy with just your eyes.)

A successful amateur astronomer needs to be able to navigate the night sky. This means learning how to locate and identify major stars and constellations — the heavenly equivalent of marker buoys. To find your way, step out under the night sky, and bring along the pull-out star chart from the current month's issue of *Astronomy* and a flashlight whose lens you covered with red cellophane (this preserves your night vision). For more help, look for Senior Editor Richard Talcott's 5-minute tutorial "How to use a star chart" in the how-to video section of www.Astronomy.com.

Binoculars

Perhaps you want to make a few forays into the cosmic sea. What next? How about the observing equivalent of a rowboat — binoculars! An important astronomical tool, binoculars bridge the gap between naked eyes and telescopes.

While any binocular will suffice for backyard astronomy, I recommend either the 7x50 or 10x50 size. The first number is the magnifying power, and the second defines the width of the front lenses in millimeters. Smaller binoculars like 7x35 will work, but they collect much less light than the 50-millimeter versions. This greater light-gathering ability means you can glimpse fainter sky objects.

If you don't already own binoculars, or the ones you have are too small, you can purchase some at reasonable prices. While 7x50 or 10x50 binoculars can cost as little as $30, a high-quality pair will run about $150. Some features you should look for in binoculars are a "Porro" prism design, the ability to individually focus each eye, and prisms made from BaK-4 glass.

Binoculars can capture a surprisingly large and diverse array of sky objects. Start with our nearest neighbor in space, the Moon. Your best views this month are between the 14th and 21st. Binoculars will reveal some of the Moon's major features.

For a list of summer binocular targets, visit www.Astronomy.com/toc.

▲ **Good observers** should know their way around the constellations. The best way to learn how to navigate the sky is to use just your eyes and an inexpensive observing tool called a planisphere. Cygnus the Swan (left) and Lyra the Lyre (bottom right) are two constellations visible in northern summer. Bill and Sally Fletcher

Want to go deeper into space? Recline in a lawn chair and take a "Milky Way cruise" from Cassiopeia the Queen to Sagittarius the Archer. The sheer number of stars, clusters, and nebulae you encounter will dazzle you.

The telescope

So far, you've entered the shallow end of the cosmic sea using your naked eyes and binoculars. Maybe you feel it's time to purchase a telescope and sail the high seas. I'm not telling you to go out and buy an astronomical yacht — a huge, expensive, high-tech instrument with more bells and whistles than a three-ring circus. Instead, look for the astronomical equivalent of a sailboat — a telescope modest in size and cost, but still sky-worthy. A no-frills 6- or 8-inch reflector that's Dobsonian-mounted fits the bill. They're easy to set up and use,

Our nearest neighbor, the Moon, is a great observational target for the naked eye, binoculars, or a small telescope. Adam M. Stuart

The Pleiades star cluster (M45) is visible to the naked eye, although it looks more like a fuzzy splotch as compared to this photograph. For a much better view, use binoculars. George Greaney

and capable of capturing enough deep-sky objects to keep you busy for a lifetime.

"No frills" means just that. When you purchase such a telescope, you get the optical tube assembly and mount, a pair of eyepieces (low and high power), and a finder scope for aiming. A no-frills 6-inch Dobsonian retails for between $250 and $300; another $50 to $100 will land you an 8-inch diameter scope. Pricier versions equipped with electronic "go-to" options that automatically direct the telescope to the target with the push of a button aren't necessary. A good star atlas and your finder scope will suffice to locate almost any sky object.

And what an array of sky objects you'll see! The Moon, with its rugged, cratered terrain is a spectacular telescopic sight. Venus, currently a dazzling beacon in the western sky after sunset, will captivate you with its half-Moon appearance. You'll marvel at the gemlike appearance of double stars like Mizar (Zeta [ζ] Ursae Majoris) and Albireo (Beta [β] Cygni). Try your luck with the Wild Duck Cluster (M11), the Hercules globular cluster (M13), the Ring Nebula (M57), and other deep-sky objects. Each issue of *Astronomy* also describes currently observable telescopic treats from solar system to deep space.

If you thought of the night sky as a playground for only the wealthy, think again. For a few hundred dollars, you can sail virtually anywhere in the universe. Bon Voyage!

A few more supplies

A well-equipped sailor doesn't set out on the ocean without charts and mariner's handbooks. Neither should you venture out into the cosmic sea without basic guidance. Consider purchasing the following:

Planispheres

As useful as *Astronomy*'s pullout star charts are, they restrict you to a specific date and time. Here's where a device called a planisphere comes in handy. It consists of a pair of thin cardboard or plastic disks that rotate around a pivot point. Dial in the date and time, and a window on the upper disk reveals the stars and constellations visible at that moment. Most planispheres cost between $5 and $15, but several websites offer free do-it-yourself versions. Be sure the planisphere you select is designed for your latitude.

Constellation guidebooks

I'm fond of two constellation primers. The first is Chet Raymo's *365 Starry Nights* (Fireside, 1990), which takes you on a night-by-night tour of the stars and constellations and includes in-depth descriptions of the wonders encountered on the way. Another excellent guidebook is *The Monthly Sky Guide*, 8th Edition, by Ian Ridpath and Wil Tirion (Cambridge University Press, 8th edition, 2009). As the name implies, it's a monthly tour of the sky. Each of these guides costs about $10.

Basic star atlases

Whether you consult *Astronomy*'s foldout sky chart or a planisphere, you get a view of the night sky similar to what a world globe provides geographers. To zoom in on a particular country, they use a world atlas; for a detailed look at a constellation, the observer turns to a star atlas. If you want an easy-to-use basic star atlas, consider *Astronomy*'s just-published *Atlas of the Stars: New Edition*.

Guidebooks

For binoculars, you can't go wrong with Phil Harrington's *Touring the Universe through Binoculars* (Wiley, 1990), or Stephen James O'Meara's *Observing the Night Sky with Binoculars* (Cambridge University Press, 2008). For the consummate guide to all aspects of backyard astronomy, look for Terence Dickinson's *Nightwatch* (Firefly, 4th Edition, 2006). Each of these handbooks costs between $20 and $30. — *G. C.*

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Find your way through the fall sky

Easy-to-recognize star patterns, bright stars, and the Milky Way are just some of what the autumn sky has to offer.

by Michael E. Bakich

Fall is a great time for stargazing. Evenings arrive more quickly than in the summer, and all the stress from traveling or getting the kids ready for school lies in the past. And although the fall sky may not contain the most brilliant stars, great targets abound. The Milky Way arches from the northeast to the southwest, and it contains countless wonders. Set up a reclining chair at a dark site and scan our galaxy's spiral arms with just your eyes or through binoculars. You'll be glad you did.

Let's start our tour high overhead. As the glow of sunset wanes, you'll spot the three bright stars that form the Summer Triangle: **Vega** (Alpha [α] Lyrae) in **Lyra** the Harp, **Altair** (Alpha Aquilae) in **Aquila** the Eagle, and **Deneb** (Alpha Cygni) in **Cygnus** the Swan. Deneb marks the tail of the Swan, and **Albireo** (Beta [β] Cygni) is its head. Albireo makes a terrific small-telescope target: a double star that glows gold and blue.

But the Summer Triangle isn't the only geometric figure you'll find in the fall sky. Look east of the Summer Triangle for four stars that form the main part of the constellation **Pegasus** the Winged Horse. Astronomers call this stellar quartet the Great Square, and it's the easiest way to find the legendary horse. Pegasus is a huge constellation that spreads out toward the west from the Great Square.

From a dark site, point binoculars or a telescope about half a binocular field of view west-northwest of magnitude 2.4 Enif (Epsilon [ε] Pegasi). There, you'll find a bright globular cluster with the designation **M15**.

The northeast star of the Great Square doesn't belong to Pegasus. It's Alpheratz (Alpha Andromedae), the brightest star in **Andromeda** the Princess, which appears as two lines of stars that start at Alpheratz and curve to the northeast.

Follow the northern curve for two stars to magnitude 3.9 Mu (μ) Andromedae. Then look about half a binocular field northwest, and you'll spot the **Andromeda Galaxy** (M31), the northern sky's greatest galaxy. You can see it without optical aid from a dark site, where it will appear as a faint piece of the Milky Way that broke off. But it's not part of our galaxy. Rather, it's a separate system that numbers nearly half a trillion stars. That many stars give off an incredible amount of light, but M31 still appears faint because of its distance. Although M31 is one of the nearest galaxies to us, it lies some 2.5 million light-years away.

Stellar designations

Notice what follows the names of the bright stars in this story. Let's use Vega (Alpha [α] Lyrae) as an example. After the star's common name, you'll see a Greek letter, its symbol, and the possessive form of the constellation name. (We list the Greek letter only the first time it appears in an article.)

Only a few hundred stars have proper names, but about a thousand have Greek letters associated with them. This practice began with German mapmaker Johann Bayer (1572–1625) in his star atlas *Uranometria*, published in 1603. Astronomers have used his designations — with few additions or deletions — ever since.

Both images: Bill and Sally Fletcher

Pegasus the Winged Horse lies low in the east early in the fall. By season's end, most northern observers will find it high overhead. Look for the four stars that mark the Great Square.

Michael E. Bakich *is an* Astronomy *senior editor and former planetarium lecturer.*

Cassiopeia the Queen lies in one of the Milky Way's richest star fields. The five bright stars that form the W are easy to spot. This photo also reveals the Andromeda Galaxy (M31) which lies 15° south (to the lower right in this image) of Cassiopeia's brightest star.

Just north of Andromeda, look for the bright constellation **Cassiopeia** the Queen. Depending on the time of night, the five luminaries of this star group will appear either as the letter W or M. Cassiopeia lies smack-dab in the Milky Way, so it's full of tightly packed star clusters you can spot through binoculars.

The W of Cassiopeia opens toward the north and the constellation **Cepheus** the King. This star group will test your ability to find objects because none of its stars is bright. Search for five stars that look like a pencil sketch of a house.

Cepheus lies midway between Cassiopeia's W and **Polaris** (Alpha Ursae Minoris), the North Star. At magnitude 2.0, Polaris ranks as the 47th-brightest star, which is still pretty bright.

But it's not the star's brightness that makes it famous. Rather, its position near the North Celestial Pole (the point toward which Earth's axis aims) means that, of all visible stars, Polaris is the one that doesn't appear to move. Because it seems fixed, you can use it to find north.

Next, return to Queen Cassiopeia's W figure. Use binoculars to search two binocular fields of view east of Cassiopeia for the **Double Cluster** (NGC 869 and NGC 884), which lies just above the head of the constellation **Perseus** the Hero. Although you can spot both clusters as fuzzy objects without optical aid, binoculars really bring out their best.

At the other end of Perseus, you'll find the fall sky's best naked-eye/binocular deep-sky object: the **Pleiades** (M45). Early in the fall, M45 doesn't rise until several hours after sunset, but it's worth the wait. With your naked eyes, you can see six Pleiads in the form of a tiny dipper. It's not the Little Dipper, however. That star group — part of the constellation Ursa Minor — lies in the north.

Through binoculars, three dozen stars will dazzle you. For M45, a magnification between 10 and 15 times works best. If possible, mount your binoculars on a tripod because high-power units tend to weigh more, and your arms will fatigue long before you get tired of the view.

That's not a comet

In amateur astronomy, the letter "M" before any number from 1 to 109 stands for "Messier object." French comet-hunter Charles Messier (1730–1817) compiled a list of 109 celestial objects. Through the small telescopes of Messier's day, such objects resembled comets. He wanted other observers to realize they weren't comets, however. Through today's scopes, these objects are no longer nuisances, but worthy observing targets. Messier's list contains some of the finest star clusters, nebulae, and galaxies visible.

Once you learn the bright stars and constellations in the fall sky, it will be easy for you to transition to the other three seasons. In a short time, you'll be locating lots of great celestial objects to share with others. And you won't even need a star map.

You'll find all highlighted objects on the StarDome at www.Astronomy.com.

The Ceravolo 300 Astrograph: two scopes in one

This telescope's dual optical configuration offers wide-field and close-up imaging. **by Bob Fera**

The 300 Astrograph gives users the option of an f/4.9 or an f/9 focal ratio. Switching between the two is simple. Just change out the field corrector lens.

The field of astroimaging has exploded with equipment choices. One recent entry is the Ceravolo 300 Astrograph. Veteran amateur astronomers will recognize the name Peter Ceravolo, renowned optical designer who has designed and built systems for more than 30 years. He began Ceravolo Optical Systems in 1994. The company built the optics for Canada's Microvariability and Oscillations of Stars (MOST) space telescope. It also produced a line of Maksutov-Newtonian telescopes optimized for high-resolution visual work.

In 2003, Ceravolo saw a need for wide-field imaging that took advantage of large CCD chips. The first product of that work is the 300 Astrograph, and I jumped at the chance to test it.

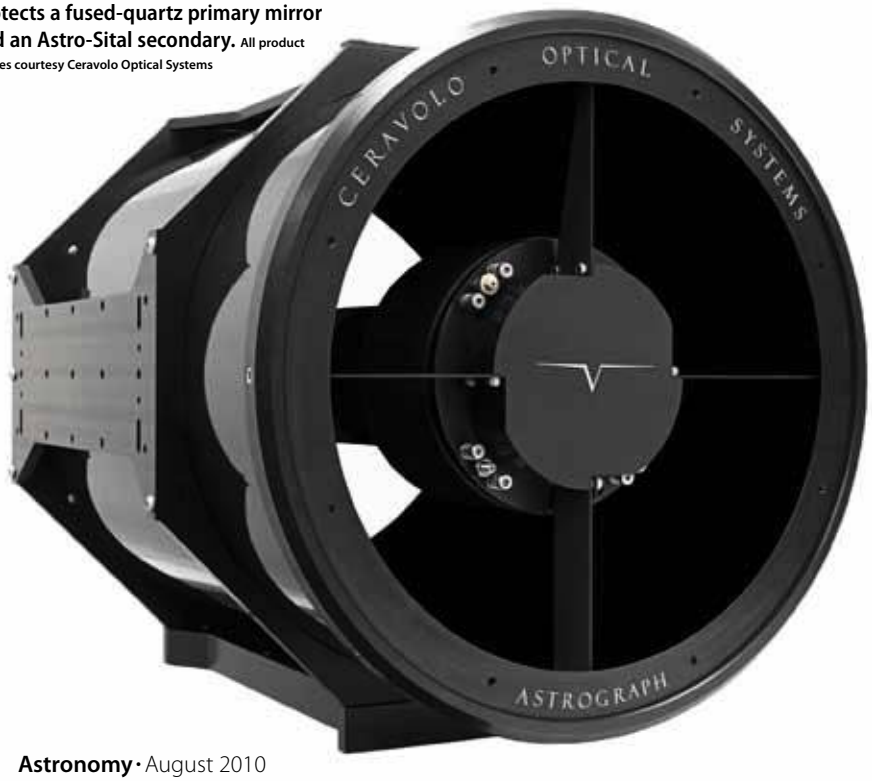
Under the hood

The 300 Astrograph features many intriguing design elements. The optics classify as Dall-Kirkham Cassegrain, but with a three-element field-corrector lens located behind the 11.8-inch (300 millimeters) primary mirror. This combination yields a flat, coma-free field large enough to cover today's CCD chips.

From the start, Ceravolo wanted to produce a system versatile enough for both wide- and narrow-angle targets. Most manufacturers do this by building a long-focal-length system and adding a removable telecompressor lens. Ceravolo reasoned, however, that to retain the highest image quality, it was better to build a short-focal-length system and employ a tele-extender lens when necessary. So, in its native configuration, the 300 Astrograph operates at f/4.9 with a focal length of 1,470mm. Replace the corrector lens, however, and you transform the scope into an f/9 system with a 2,700mm focal length that provides the same flat, corrected field.

The optical system gives the 300 Astrograph a powerful advantage over telescopes with other configurations. Because the scope's two mirrors have

The Ceravolo 300 Astrograph is a Dall-Kirkham Cassegrain reflector with an aperture of 11.8 inches (300 millimeters). Its carbon-fiber tube protects a fused-quartz primary mirror and an Astro-Sital secondary. All product images courtesy Ceravolo Optical Systems



Product specifications

Ceravolo 300 Astrograph
Type: Dall-Kirkham Cassegrain reflector
Aperture: 11.8 inches (300 millimeters)
Focal ratios: f/4.9 and f/9
Focal lengths: 1,470mm at f/4.9; 2,700mm at f/9
System weight: Approximately 50 pounds (22.7 kilograms)
Includes: Pre-collimated primary mirror, carbon fiber tube, Optec TCF-S focuser, thermally isolated aluminum cradle, four side plates with accessory mounting holes, heavy-duty front end ring, front and back aluminum dust covers, either the f/4.9 or f/9 field corrector (The price for the second field corrector is $1,995)
Price: $18,995

simple figures (the primary is elliptical, and the secondary is spherical), collimation is a simple task. Ceravolo factory-aligns the primary and fixes it in place, so the only adjustment needed is the tip/tilt of the secondary mirror. Two orthogonal control knobs accomplish this.

The combination of a fused-quartz f/2 primary, an Astro-Sital secondary, and a 20-inch carbon fiber tube translates to a thermally and mechanically stable system. Ceravolo includes an Optec TCF-S focuser, one of the most rugged and stable available. Integrated electronics allow control of the focuser, cooling fans, and dew heaters by a personal computer.

Test experience

I first tested the 300 Astrograph at f/4.9. The scope's somewhat restricted back-focus combined with the Optec focuser's generous size eliminates the possibility of using an off-axis guider, so I mounted a guide scope to the tube. This arrangement was fine for guiding, and my Astro-Physics 1200 mount easily handled the 50-pound (22.7 kilograms) weight.

The 300 Astrograph comes with several large-diameter extension tubes, which easily let me position my CCD camera at the optimal focus position. Ceravolo bolts (rather than threads) its extension tubes together. This provides a superior connection.

For my test during the summer of 2009, the only way to focus was via the supplied software. This was the system's only weak point because the program was in testing at the time. Also, because no ASCOM driver (that allows software to "talk" to instruments) was available, autofocusing was not possible. No more. Current scopes include both ASCOM drivers and the ability to use the Optec hand controller.

Collimating the scope is easy. Just turn one of the two knobs that control the orthogonal motion of the secondary mirror.

The Witch's Broom (NGC 6960) shows vibrant, true colors and sharp stellar images to the edge of the field when the author imaged it with the Ceravolo 300 Astrograph at f/4.9. Bob Fera

Once I set up, I turned the 300 Astrograph to my first target, the Crescent Nebula (NGC 6888) in Cygnus, and the results delighted me. The wide field provided a panoramic vista of nebulosity around the Crescent with nice sharp stars out to the edges of my SBIG STL-11000M CCD camera's chip. Shots of the Butterfly Nebula (IC 1318) in Cygnus and the Snake Nebula (Barnard 72) in Ophiuchus reinforced my positive impressions from my initial images.

Testing, part 2

The following month, it was time to try the 300 Astrograph at f/9. This required removing the camera, focuser, and extension tubes, and then replacing the corrector lens assembly at the telescope's rear. The only tools that I needed were hex wrenches, so installing the lens was easy.

At f/9, the 300 Astrograph has a few inches of additional back-focus, which had several ramifications. It meant I could insert an off-axis guider into the system, but I also had to re-balance the scope. After going through the expected first-light gyrations of figuring out which extension tubes to use and touching up the collimation, I was ready to go.

While inspecting my initial shot, I noticed some odd aberrations in stars at the corners. I sent my image to Ceravolo, and he immediately identified the problem: The focal plane was not square to the telescope's axis. Clearly I had failed to tighten some set screws sufficiently while connecting my camera and guider because I had no such troubles at f/4.9. Unfortunately, other commitments prevented me from correcting the problem before I had to return the scope. However, I have examined other images taken through the 300 Astrograph at f/9. The shots show perfect stars to the corners, so I'll call my problem "pilot error."

Top-of-the-line gear

I had a great time testing the Ceravolo 300 Astrograph. It is a beautiful instrument you'll be proud to own. It also lives up to each of its promises: excellent image quality, versatility, and ease-of-use — a difficult combination, but one that makes for an enduring telescope.

Bob Fera *is a dedicated astroimager and long-time contributor to* Astronomy. *He images from Mount Pinos in the Los Padres National Forest.*

Contact information

Ceravolo Optical Systems
100 Craig Henry Drive, Unit 102
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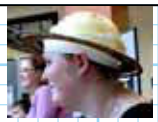
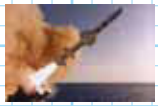
The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD

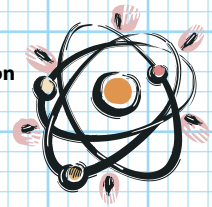


Saturn on your mind
A Maine museum and local cancer support group host the 4th annual "Planet Head Day," honoring both cancer survivors and planetary science.



Missile commander
The Department of Defense starts testing airborne lasers meant to bring down missiles. They can fire up to 20 shots without having to reload; more if you know the Contra Code or have a Game Genie.

Next up, perpetual motion
YouTube user "AlienScientist" posts a video titled, "AntiGravity Physics Explained." You know, in case you were curious.



Quarky actress
Anne Hathaway tells *GQ*, "I'm dying for someone to explain quarks to me!" Well, Anne, that's the kind of thing best explained over a candlelit dinner.

CSI: NASA
The lasers NASA will use on its next Mars rover could also be useful for analyzing forensic evidence. Finally, lasers that can stop criminals!

Law and orbit
Twenty-seven members of Congress write to NASA Administrator Charles Bolden warning that canceling the Constellation program could break the law, giving Pluto's biggest supporters all kinds of ideas.

Dancing among the stars
Buzz Aldrin, the second person to walk on the Moon, is also the second person kicked off *Dancing with the Stars*. Apparently, voters are stupid; we love you Buzz!

Real life sci fi
Apple's iPad strongly resembles Arthur C. Clarke's fictional "Newspad," a hand-held device from *2001: A Space Odyssey* capable of displaying numerous publications. Looks like something from that book came true after all!

Astronomical calculations
The website www.howmanypeopleareinspacerightnow.com debuts, with resounding (if uncomplex) success.

Movie math
Scientists discover Hollywood movies can be accurately described using a mathematical formula. Funny, we always thought it was just "sequel + explosions = money."

HOT

NOT

Movie science
The National Science Foundation (NSF) and the University of Southern California School of Cinematic Arts plan to join forces to make scientifically accurate movies. Let's hope Brad Pitt plays the NSF director in the thrilling adaptation.

Martian décor
A Craigslist ad offers a "Rover / Coffee Table for Sale" for only $2 million. It's likely a fake, but after NASA discounted the space shuttles, it's hard to know for sure.

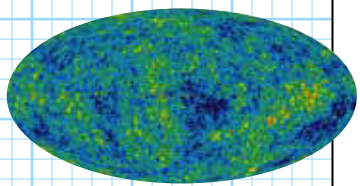
Past futures
Space.com reports that "Moon tourism" may be popular by 2020, making the 1960s really excited its future might still come to pass.

ISS research
A NASA briefing focuses on the glow-in-the-dark plants grown aboard the International Space Station. And people think they don't do real science there!

Light chocolate
Wired's GeekDad blog explains how to use leftover chocolates to determine the speed of light. As if chocolate wasn't good enough already!

iRover
NASA releases an iPhone game allowing players to drive a proposed lunar rover near a potential future lunar landing site. Once again, half the fun of new technology is seeing what NASA does with it.

Into the sunset
Shuttles *Discovery* and *Endeavour* are due to launch for the last time in the coming months, with *Atlantis*' final flight already over. Whatever your politics, we can all agree they've had a good run.



Exploiting dark energy
A new video game features characters that can harness dark energy to move objects and fight enemies. OK, there's a lot we don't know about dark energy, but that still seems a bit farfetched.

ISS, now with a view
Astronauts install the cupola, an "observatory module," in the International Space Station. Another name for observatory module? Awesomely huge window.

PREDICTABLE

PHOTOGRAPHS: Frank Grant, http://www.youtube.com/watch?v=sh2P7A6Y9yY (Saturn on your mind); PhotoSpin, Inc./Stocktrek (Missile commander); © 2009 Jupiterimages Corporation (CSI: NASA); John Harrison (Quarky actress); Apple (Real life sci fi); Brad Eshbach (Astronomical calculations); © 2009 Jupiterimages Corporation (Next up, perpetual motion); PhotoSpin, Inc./Marcio Silva (Law and orbit); ABC/Adam Larkey (Dancing among the stars); © 2009 Jupiterimages Corporation (Movie math); NASA (Past futures); NASA (ISS research); NASA (Into the sunset); NASA/WMAP Science Team (Exploiting dark energy); NASA/JPL-Caltech (Martian décor); © 2009 Jupiterimages Corporation (Light chocolate); NASA (iRover); NASA (ISS, now with a view)

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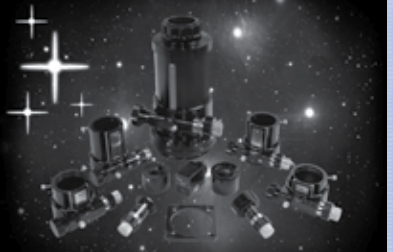

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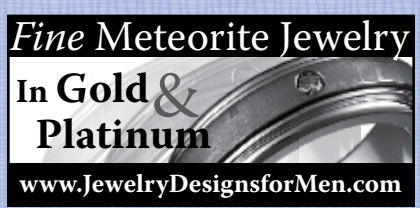

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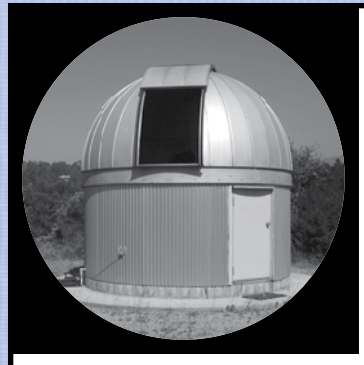

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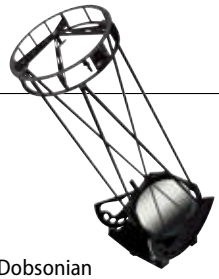

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NEXT MONTH
in the September issue

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Tony Hallas kicks off astroimaging column

California amateur astronomer Tony Hallas is one of the top celestial photographers on Earth. Starting in *Astronomy*'s September issue, he'll share his expertise in a monthly column called "Imaging the Cosmos."

Hallas, a self-taught photographer, has captured celestial objects, first on film and then with CCD cameras, since 1987. For more than 2 decades, he has contributed many striking images to the pages of *Astronomy*. In fact, in the September 2009 issue, Hallas won *Astronomy*'s 2009 Astroimaging Contest with a stunning image of the Andromeda Galaxy (M31) that required more than 200 exposures totaling some 19 hours.

In his exclusive *Astronomy* column, Hallas will focus on techniques applicable even to beginning astrophotographers. That's because much of his success comes after he acquires the image. Whether you're a beginning shutterbug or a longtime celestial photographer, you will learn more about imaging from Hallas' column.

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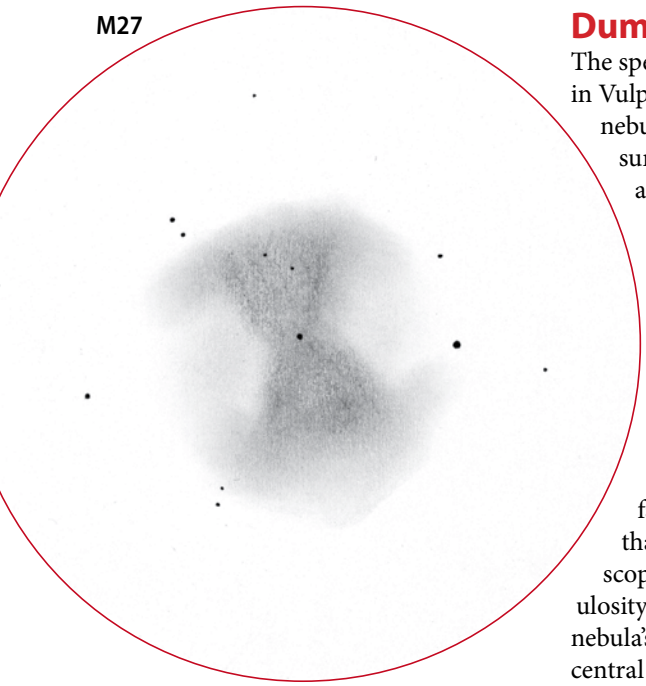
Deep-sky Showcase

Astronomy's *editor sketches two of his favorite objects.* **by David J. Eicher**

The Dumbbell Nebula and NGC 7006

M27



The Dumbbell Nebula sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.

Dumbbell Nebula (M27)

The spectacular Dumbbell Nebula (M27) in Vulpecula is one of the finest planetary nebulae in the sky. This object's high-surface-brightness disk is visible in any telescope. Celebrated for its dumbbell or apple-core shape, the nebula spans 8' by 5.6' and glows at magnitude 7.5; even binoculars show it as a hazy little patch located inside a circular grouping of bright stars.

A 6-inch scope under a dark sky shows the dumbbell shape and perhaps even the "ears" of faint, low-surface-brightness gas that extend outward. Larger telescopes reveal an extensive halo of nebulosity around the Dumbbell and the nebula's 13th-magnitude central star. The central star itself is but one of a number of stars apparently floating inside the nebula (the others are foreground stars).

M27

Joe and Gail Metcalf/Adam Block/NOAO/AURA/NSF

Designations: M27, NGC 6853
Position: 20h0m, 22°43' (2000.0)
Constellation: Vulpecula
Magnitude: 7.5
Size: 8.0' by 5.6'
Distance: 1,360 light-years

You might try drawing the Dumbbell on paper to sharpen your acuity. Use plain white paper, draw a circle to represent the field of view, and employ a soft pencil. First draw the stars and then shade in the nebulosity. This will produce a record of your observation for future reference.

NGC 7006

Preston Scott Justis

Designation: NGC 7006
Position: 21h01m, 16°11' (2000.0)
Constellation: Delphinus
Magnitude: 11.4
Size: 2.8'
Distance: 130,000 light-years

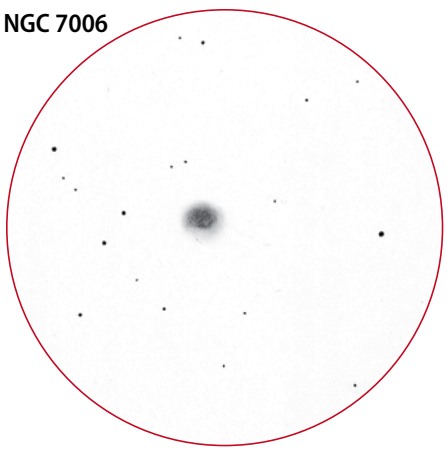
NGC 7006

Relatively nearby, in Delphinus, lies a deep-sky object that is approximately 100 times more distant than the Dumbbell. The remote globular cluster NGC 7006 is a challenging object for observers and is more distant from the Sun than the width of our galaxy's bright disk component.

Glowing dimly at magnitude 11.4 and measuring only 2.8' across, NGC 7006 is not terrifically impressive for small scopes. The thrill of the hunt is key here, though, as it is one of the most distant globular clusters visible through small telescopes. A 6-inch scope reveals a small smudge of light; a large backyard telescope reveals the central region to be brighter, set amid a rich field of stars, but does not resolve the cluster's edges.

A large scope will show a distinctly bright knotlike core, however, shrouded in a fainter haze. The surrounding star-field is peppered with faint suns, each of which is a foreground star. They offset the fuzzy glow of the cluster nicely.

NGC 7006



NGC 7006 sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 34 years.*

reader gallery

The CARMA telescope array (Nikon D700 digital SLR, Nikkor 28mm lens at f/4, ISO 1000, 96-second exposure) • Tony Rowell, Bishop, California

Barred spiral galaxy M95 in the constellation Leo the Lion lies about 38 million light-years away. This galaxy's bar acts as a form of stellar nursery. It channels gas and dust from the spiral arms inward, in effect funneling a flow of the ingredients required to create stars. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG STL-11000 CCD camera, LRGB image with exposures of 300, 75, 75, and 75 minutes, respectively) • R. Jay GaBany, San Jose, California

Astronomy in millimeters

The Combined Array for Research in Millimeter-wave Astronomy (CARMA) consists of six 10.4-meter, nine 6.1-meter, and eight 3.5-meter antennas that image the sky at millimeter wavelengths from California's White Mountains. A consortium of five universities operates CARMA with funding from the National Science Foundation and member institutions.

Tony Rowell waited 3 months for permission to photograph CARMA. His friend, astronomer Paul Rasmussen, invited him there one evening and turned off the dishes' lights for a few minutes while Rowell imaged the Milky Way. Near the end of the exposure, he used a Dorcy 3-million-candlepower spotlight to illuminate the dishes.

Reflection nebula IC 426 in Orion lies 0.9° due north of magnitude 1.7 Alnilam (Epsilon [ε] Orionis). (10-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG ST-10XME CCD camera, LRGB image with exposures of 360, 195, 195, and 195 minutes, respectively, taken at New Mexico Skies telescope rental site near Mayhill, New Mexico) • Eric Africa, West Chester, Ohio

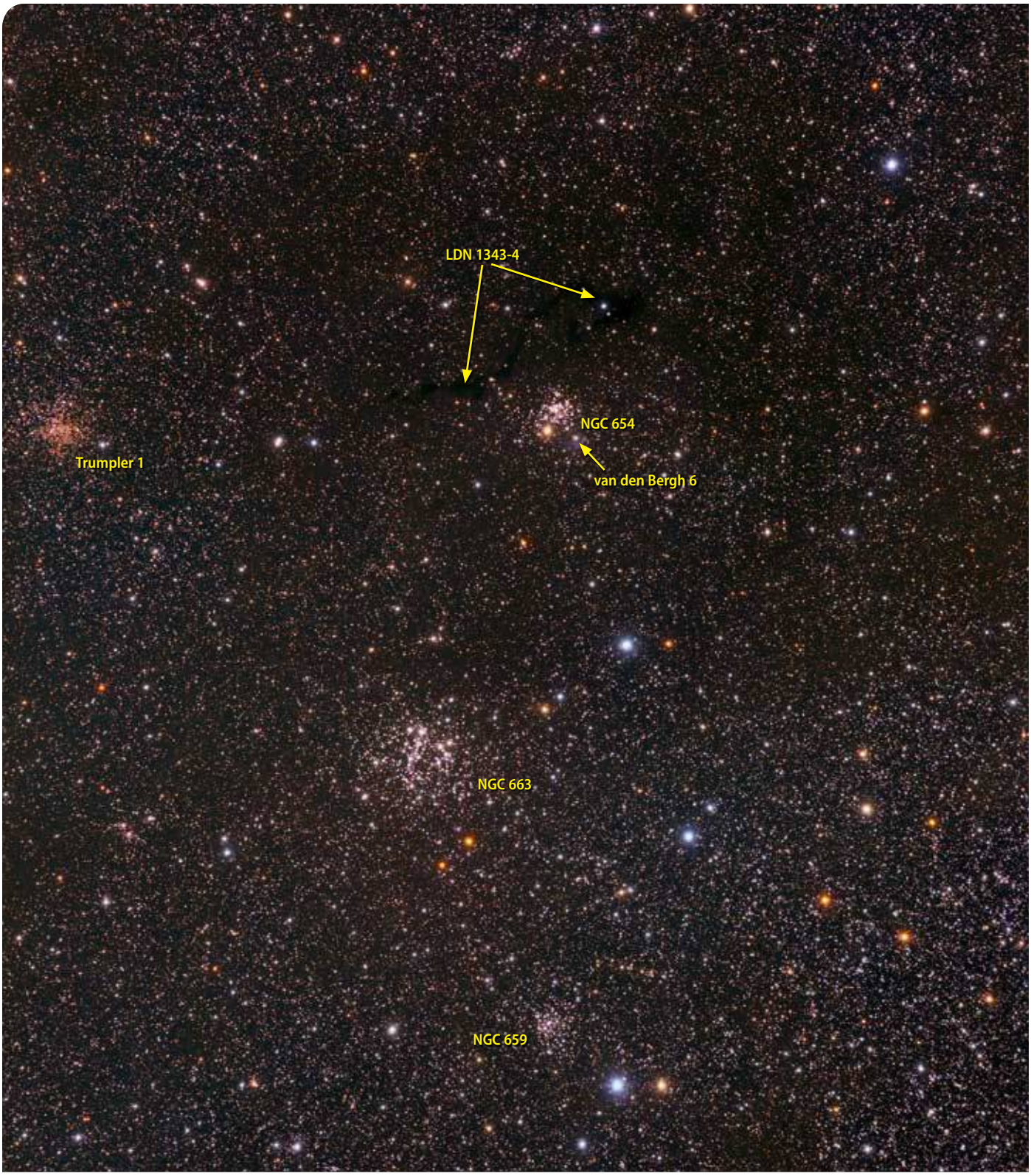
▲ **The Little Dumbbell Nebula** (M76) in Perseus sits 1° north of the 4th-magnitude star Phi (ϕ) Persei. At magnitude 10.1, M76 ties for the designation as "Messier's faintest object" with galaxies M98 and M91 from that catalog. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-6303E CCD camera, LRGB image with exposures of 200, 95, 95, and 95 minutes, respectively) • Mark Manner, Nunnelly, Tennessee

▶ **Globular cluster M56** in Lyra is one of the lesser known and dimmest globular clusters in the Messier catalog. With a magnitude of 8.4 and most of the member stars being only as bright as 13th magnitude, this Messier object is easy to overlook. The cluster measures 7.1' across. (6.3-inch Astro-Physics AP160 StarFire EDF refractor at f/7.5, SBIG ST-2000XM CCD camera, LRGB image with 30-minute exposures through each filter) • Anthony Ayiomamitis, Athens, Greece

Venus stood 6.5° to the upper left of a young crescent Moon that appeared in the western evening sky in mid-March. At the time of this image, the Moon was only 27 hours and 9 minutes past its new phase. (Canon 50D digital SLR, 100mm lens at f/3.5, ISO 100, 3-second tripod-mounted exposure, taken March 16, 2010, at 8:10 P.M. EDT from Big Bay, Ontario) • Steve Irvine, Wiarton, Ontario

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.



Reflection nebula van den Bergh 6 lies in a rich Milky Way region in the northern constellation Cassiopeia the Queen. Note that within this varied image, only the tiny blue nebula to the lower right of open cluster NGC 654 is van den Bergh 6. (12-inch Astro Systeme Austria N12 astrograph at f/3.5 and a 5-inch Tele Vue 127is refractor at f/5.2, FLI ProLine 16803 and SBIG STL-11002CM CCD cameras for monochrome and color data, respectively, 300 minutes of monochrome images stacked with 310 minutes of color images) • Thomas V. Davis, Inkom, Idaho

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